



**The Department of  
Water, Land and  
Biodiversity  
Conservation**

# **The Environmental Weed Risk of Revegetation and Forestry Plants**

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## Foreword

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The Department of Water, Land and Biodiversity Conservation seeks to ensure the environmentally sustainable use and development of South Australia's land and water resources. Often there are perceived conflicts of interest between economic development in primary industries and the protection of our natural heritage. It is vital that we investigate such conflicts and seek to develop solutions that maximise benefits and minimise costs, both economic and environmental, to the community.

In 1999 the Animal and Plant Control Commission (APCC) produced guidelines on the risk assessment and management of olives. Feral olives are one of South Australia's most important bushland weeds, having significant impacts on biodiversity. Yet the expanding olive industry has the potential for significant economic contribution to the state. The APCC guidelines sought to minimise the risk of spread of olives from new orchards. The guidelines were a watershed in formally recognising the environmental weed risk of an economic crop in South Australia, and in providing a means to manage this risk.

This report follows the lead of the olive guidelines and considers the environmental weed risk of a range of trees, shrubs and grasses which have been planted for use in broad scale rural revegetation and farm forestry. The DWLBC Revegetation Program and the State Revegetation Committee are to be congratulated for initiating this project. The report provides comprehensive evidence of the significant weed risk of some species and also the minimal weed risk of others. Suggestions are given on how the weed risk of various species can be managed more effectively. The challenge for the future is to engender a sense of "responsible plant ownership" into our community to ensure we reap the benefits of plants whilst minimising their unintended spread to our natural areas.

**Roger Wickes**

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# CONTENTS

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FOREWORD .....	III
CONTENTS .....	II
ABSTRACT .....	5
INTRODUCTION .....	7
AIM .....	12
METHODOLOGY .....	13
RESULTS: TREES .....	19
RESULTS: SHRUBS .....	70
RESULTS: GRASSES .....	109
DISCUSSION .....	136
CONCLUSIONS & RECOMMENDATIONS .....	143
ACKNOWLEDGEMENTS .....	152
GLOSSARY .....	154
REFERENCES .....	155
APPENDIX A .....	170

## List of Tables

Table 1.	Scientific and common names of the twenty species assessed. ....	12
Table 2.	Weed risk classifications.....	18
Table 3.	Regional proportions of native vegetation with potential for invasion by <i>Casuarina glauca</i> .....	23
Table 4.	Regional proportions of native vegetation suitable for <i>Eucalyptus cladocalyx</i> .....	29
Table 5.	Regional proportions of native vegetation with potential for invasion by <i>Eucalyptus globulus</i> spp. <i>globulus</i> .....	35
Table 6.	Regional proportions of native vegetation with potential for invasion by <i>Eucalyptus occidentalis</i> .....	41
Table 7.	Regional proportions of native vegetation with potential for invasion by <i>Eucalyptus platypus</i> .....	45
Table 8.	Regional proportions of native vegetation with potential for invasion by <i>Pinus brutia</i> .....	51
Table 9.	Regional proportions of native vegetation with potential for invasion by <i>Pinus halepensis</i> .....	57

Table 10.	Regional proportions of native vegetation with potential for invasion by <i>Pinus radiata</i> .....	63
Table 11.	Summary of criterion and final scores for the tree species for southern SA within the native vegetation landuse. ....	68
Table 12.	Weed Importance scores for the tree species for different regions.....	69
Table 13.	Regional proportions of native vegetation suitable for <i>Acacia cyclops</i> . ....	76
Table 14.	Regional proportions of native vegetation with potential for invasion by <i>Acacia saligna</i> .....	82
Table 15.	Regional proportions of native vegetation with potential for invasion by <i>Atriplex amnicola</i> .....	86
Table 16.	Regional proportions of native vegetation suitable for <i>Atriplex nummularia</i> spp. ....	91
Table 17.	Regional proportions of native vegetation with potential for invasion by <i>Chamaecytisus palmensis</i> .....	97
Table 18.	Regional proportions of native vegetation with potential for invasion by <i>Medicago sativa</i> .....	102
Table 19.	Summary of criterion and final scores for the shrub species for southern SA within the native vegetation landuse. ....	107
Table 20.	Weed Importance scores for the shrub species for different regions. ....	108
Table 21.	Regional proportions of native vegetation with potential for invasion by <i>Ehrharta calycina</i> .....	114
Table 22.	Regional proportions of native vegetation with potential for invasion by <i>Puccinellia ciliata</i> .....	118
Table 23.	Regional proportions of native vegetation suitable for <i>Themeda triandra</i> .....	123
Table 24.	Regional proportions of native vegetation with potential for invasion by <i>Thinopyrum ponticum</i> .....	130
Table 25.	Summary of criterion and final scores for the shrub species for southern SA within the native vegetation landuse.. ....	135
Table 26.	Weed Importance scores for the shrub species for different regions.....	135
Table 27.	Environmental weed risk categories for the twenty species in the seven regions.....	137

## List of Figures

Figure 1.	The seven regions used in the report.....	16
Figure 2.	Areas considered as native vegetation in SA. ....	17
Figure 3.	Known locations of naturalised <i>Casuarina glauca</i> and areas of native vegetation with potential for invasion by the species in SA. ....	24
Figure 4.	Known locations of native and naturalised <i>Eucalyptus cladocalyx</i> and areas of native vegetation suitable for the species in SA. ....	30
Figure 5.	Known locations of native and naturalised <i>Eucalyptus globulus</i> and areas of native vegetation with potential for invasion by <i>E. globulus</i> spp. <i>globulus</i> in SA. ....	36
Figure 6.	Areas of native vegetation with potential for invasion by <i>Eucalyptus occidentalis</i> in SA. ....	42
Figure 7.	Areas of native vegetation with potential for invasion by <i>Eucalyptus platypus</i> in SA. ....	46
Figure 8.	Areas of native vegetation with potential for invasion by <i>Pinus brutia</i> in SA. ....	52

Figure 9.	Known locations of naturalised <i>Pinus halepensis</i> and areas of native vegetation with potential for invasion by the species in SA. ....	58
Figure 10.	Known locations of naturalised <i>Pinus radiata</i> and areas of native vegetation with potential for invasion by the species in SA. ....	64
Figure 11.	Invasiveness scoring for the tree species using the Weed Importance Scoresheet. ....	66
Figure 12.	Impacts, Potential Distribution (for southern SA) and Weed Importance scoring for the tree species using the Weed Importance Scoresheet. ....	67
Figure 13.	Known locations of native, questionably native and naturalised <i>Acacia cyclops</i> (top) and areas of native vegetation suitable for <i>A. cyclops</i> in SA.....	77
Figure 14.	Known locations of naturalised <i>Acacia saligna</i> and areas of native vegetation with potential for invasion by the species in SA.....	83
Figure 15.	Areas of native vegetation with potential for invasion by <i>Atriplex amnicola</i> in SA. ....	87
Figure 16.	Known locations of native and naturalised <i>Atriplex nummularia</i> spp. <i>nummularia</i> and areas of native vegetation suitable for the subspecies.....	92
Figure 17.	Known locations of naturalised <i>Chamaecytisus palmensis</i> and areas of native vegetation with potential for invasion by the species in SA. ....	98
Figure 18.	Known locations of naturalised <i>Medicago sativa</i> and areas of native vegetation with potential for invasion by the species in SA.....	103
Figure 19.	Invasiveness scoring for the shrub species using the Weed Importance Scoresheet. ....	105
Figure 20.	Impacts, Potential Distribution (for southern SA) and Weed Importance scoring for the shrub species using the Weed Importance Scoresheet. ....	106
Figure 21.	Known locations of naturalised <i>Ehrharta calycina</i> and areas of native vegetation with potential for invasion by the species in SA. ....	115
Figure 22.	Areas of native vegetation with potential for invasion by <i>Puccinellia ciliata</i> in SA. ....	119
Figure 21.	Known locations of <i>Themeda triandra</i> and areas of native vegetation suitable for the species in SA.....	124
Figure 24.	Known locations of naturalised <i>Thinopyrum ponticum</i> and areas of native vegetation with potential for invasion by the species in SA. ....	131
Figure 25.	Invasiveness scoring for the grass species using the Weed Importance Scoresheet. ....	133
Figure 26.	Impacts, Potential Distribution (for southern SA) and Weed Importance scoring for the grass species using the Weed Importance Scoresheet.....	134

## ABSTRACT

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Concerns have been raised about the environmental weed risk of non-indigenous plants promoted for broad scale revegetation and farm forestry purposes in South Australia (SA). Environmental weeds are plant species that invade and dominate natural habitats beyond the species' native range. The wide scale planting of species for revegetation, forestry, agriculture and horticulture increases the likelihood that some species will naturalise (i.e., form a self-sustaining population) and invade native vegetation or other landuse systems. However, analyses of past invasions have shown that the majority of plant species introductions will be of negligible weed risk. In 2001 the PIRSA Revegetation Program and the State Revegetation Committee of South Australia commissioned the Animal and Plant Control Commission (APCC) to undertake a weed risk assessment of 20 plant species.

Weed risk assessment is the use of standard, technical criteria to determine the relative weed threats posed by plant species. The APCC Weed Assessment Scoresheet multiplies scores for three criteria, 'Invasiveness', 'Impacts' and 'Potential Distribution', to give a 'Weed Importance' score. Information for assessing plants was obtained from naturalisation records of the State Herbarium of SA, a literature review, surveys of weed and native vegetation managers and forestry and revegetation experts, field observations of sites where species had naturalised. The potential distributions of each species in SA were estimated by GIS analysis, selecting areas of native vegetation that met climatic and soil tolerances for each species. Proportional areas of native vegetation at risk were calculated for seven regions of SA. Where a species was indigenous to a region it was given a Potential Distribution score of 0, assuming that the species was a desired plant (and hence not a weed) in the region. Species were ranked as very high, high, medium, low and negligible environmental weed risk on a regional basis.

Pines (*Pinus brutia*, *P. halepensis* and *P. radiata*) ranked as high to very high environmental weed risks in various southern SA regions, readily establishing in relatively undisturbed native vegetation and forming high-density monocultures in the long-term. Swamp oak (*Casuarina glauca*) has the capacity to form monocultures but such impacts were assumed limited to native vegetation sites with high soil water tables. This resulted in a low to medium weed risk in southern SA regions. Five eucalypts considered (*Eucalyptus globulus*, *E. grandis*, *E. occidentalis*, *E. platypus* and *E. saligna*) posed mostly negligible weed risks, being limited in seedling establishment and seed dispersal, being likely to only reach low densities if naturalised and being restricted by climatic and soil tolerances. The exception was sugar gum (*Eucalyptus cladocalyx*) which does establish more readily than the other eucalypts in native vegetation and which is well-suited to southern SA (being indigenous to lower Eyre Peninsula, the southern Flinders / northern Mt Lofty Ranges and KI). Sugar gum was a high and medium weed risk respectively in the Mt Lofty Ranges and South East regions.

Western coastal wattle (*Acacia cyclops*) and golden wreath wattle (*Acacia saligna*) ranked as medium to very high environmental weed risks across southern SA, with relatively efficient reproduction and seed dispersal, high density infestations already occurring in SA, and high climatic and soil suitability. Western coastal wattle is indigenous to the western Eyre region, but its indigenous status (and hence its weed risk) on the southern Eyre, Yorke Peninsula and KI are unclear. Old man saltbush (*Atriplex nummularia*) posed a negligible weed risk, being indigenous to regions in which it is climatically suited. River saltbush (*Atriplex amnicola*) from Western Australia also posed a negligible weed risk, being similarly limited in its seedling establishment and reproduction, and also suitable climate and soils suitability for much of SA. Tagasaste (*Chamaecytisus palmensis*) was a low to negligible weed risk in most regions, appearing to be limited in its ability to invade

undisturbed native vegetation. The exception was the Mt Lofty Ranges region where the large proportion of remnant native vegetation in high rainfall areas with well-drained, acidic soils increased the weed risk to high. However, other weedy legumes such as Gorse (*Ulex europaeus*) and Scotch broom (*Cytisus scoparius*) reach higher densities in this region and are a greater weed risk than tagasaste. Lucerne (*Medicago sativa*) ranked as a low to negligible weed risk in all regions.

Perennial veldt grass (*Ehrharta calycina*) was a high environmental weed risk across all of southern SA, with efficient reproduction and dispersal, the demonstrated capacity to form understorey monocultures in remnant native vegetation in SA, and a high degree of climate and soil suitability. Tall wheatgrass (*Thinopyrum ponticum*) has the capacity to form monocultures, but its invasion was assumed to be restricted to native vegetation overlying shallow soil water tables. It scored as a medium to high weed risk in regions where this habitat was more common. Puccinellia (*Puccinellia ciliata*) is much less vigorous than tall wheatgrass and was a negligible weed risk across SA. Kangaroo grass is indigenous to most of SA (thus a zero Potential Distribution score), and also had a low Impacts score (being a desired component of native vegetation). Hence kangaroo grass was a negligible weed risk.

Various weed risk management actions are suggested for species posing medium to very high weed risk. Feral pines should be proclaimed for mandatory control, and Aleppo pine (*Pinus halepensis*) proclaimed for sale and movement under the Animal and Plant Control (Agricultural Protection and Other Purposes) [APC] Act, 1986. Current revegetation advice should include warnings of environmental weed risk where warranted. Weed risk management guidelines should be developed, including routine control of seedlings, safe planting distances from native vegetation, roadsides and watercourses/swamps, and management to minimise seed set and dispersal. The community and garden/landscape industry need to become aware of the environmental weed risk of certain species, and favour safe alternatives for amenity use. Safe and effective control techniques need to be available to native vegetation managers for different species, including herbicide registrations. Native vegetation managers also need to become proactive in surveillance and early control of weed infestations which are threatening significant areas of native vegetation. Cultivar development of high economic value species needs to include selection for reduced reproductive ability.

Environmental weed risk management in SA could be improved in the longer term by making low weed risk a core requirement in selecting new species/cultivars, and by developing a policy framework for resolving conflicts of interest for new economic plants which pose significant environmental weed risks. A widely-accepted means of ranking conservation value of native vegetation areas in SA would improve weed risk assessment and prioritisation of environmental weed control programs. Consideration should also be given to the "polluter-pays" principle and to exempting only SA indigenous plants from proclamation in reviewing the APC Act.



## INTRODUCTION

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### ***The Problem of Environmental Weeds***

Internationally, invasive species are the second greatest threat to biodiversity after habitat destruction (Walker and Steffen 1997). Environmental weeds are a major component of this threat. Environmental weeds are plant species that (i) invade natural habitats beyond the indigenous range of the species, and (ii) have significant effects on biodiversity. Such species have often been introduced from overseas for agricultural or ornamental use in Australia. There are also Australian natives that are environmental weeds; for example, *Acacia baileyana* (Cootamundra wattle, from NSW) and *Sollya heterophylla* (Western Australian bluebell) have both invaded South Australian (SA) bushland. Major environmental weeds can have significant impacts on biodiversity and ecosystem health in natural habitats. There are limited resources to tackle weeds in natural areas and a preventative approach is the most cost-effective. There is a need to limit the use of species with environmental weed potential, and to manage the risks of such species spreading where there is no satisfactory alternative for a specific use (e.g., timber).

### **IMPACTS OF ENVIRONMENTAL WEEDS**

The types of impacts by environmental weeds on natural ecosystems can include:

1. Interference with Native Plants. This is a reduction in the establishment and growth of native plants through competition for moisture, light, nutrients and space, and through growth-inhibiting allelopathic chemicals. This leads to a reduction in native plant biodiversity (i.e., density, size and species number), with flow-on effects on invertebrate and vertebrate biodiversity. For example, olives, *Olea europaea*, in the Adelaide Hills have been shown to reduce native plant species richness and abundance by >50%, affecting the survival and regeneration of native shrubs and trees (Crossman 1999). Similar reductions in plant species richness have been measured for Scotch broom, *Cytisus scoparius* (Waterhouse 1986) and sweet pittosporum, *Pittosporum undulatum* (Mullet and Simmons 1995).
2. Ecosystem Health. This impact concerns changes to ecosystem structure and functioning brought about due to changes to faunal habitats, fire regime, nutrient cycling, hydrological cycling, soil formation, water quality and salinity of ecosystems. Dense thickets of blackberry (*Rubus fruticosus* agg.) can harbour foxes, which prey on native animals. Humphries et al. (1991) stressed the importance of grasses in changing fire regimes throughout many climatic zones in Australia. Scotch broom appears to increase soil nitrogen and phosphorus availability (Fogarty and Facelli 1999), paving the way for invasion by other exotic weeds that thrive in high fertility conditions. The invasion of exotic trees and shrubs (including pines and acacias) into the fynbos vegetation in South Africa has substantially increased evapotranspiration, reducing stream flows and impacting on water storage (Le Maitre et al. 1996). *Spartina* (*Spartina* spp.), and athel pine (*Tamarix aphylla*), increase soil sedimentation in estuarine mudflats and arid river systems respectively (Humphries et al. 1991). Dense infestations of salvinia reduce oxygen levels and pH in water (Parsons and Cuthbertson 1992). Leaf litter of athel pine causes soil surface salination (Litwak 1957). Only a minority of environmental weeds, termed 'transformers' by Richardson et al. (2000), have the potential to cause significant negative changes in the character, condition, form or nature of ecosystems. Invaders with dramatic ecosystem-level

effects are often of a life form that is not represented in the native species complex (Ruesink et al. 1995), such as woody species invasions of grasslands. Swarbrick (1991) rated canopy-dominant weeds as those that had the greatest effect on ecosystem structure and functioning.

3. Movement. Formation of dense, spiny thickets (e.g., by blackberry) may prevent or slow movement of animals or people. For example, on islands African boxthorn (*Lycium ferocissimum*) has impeded seal breeding (Hussey et al. 1997). Such thickets may also harbour vertebrate pests such as rabbits and foxes.
4. Animal and Human Health. This includes physical injuries by spiny weeds (e.g., innocent weed, *Cenchrus ciliaris*), toxic injuries from ingestion of poisonous weeds (e.g., waterfowl poisoning by castor bean, *Ricinus communis* - Littlefield 1996) and allergic reactions (e.g., poison ivy, *Toxicodendron radicans*, and grass pollens). Severe injuries or deaths from weeds are rare, as such weeds are often avoided.
5. Hybridisation. This is a relatively understudied impact, and as such it is difficult to gauge the likelihood and long-term consequences of hybridisation in natural habitats. Vila et al. (2000) distinguishes four pathways of hybridisation; hybridisation between native species which had been previously geographically separated, hybridisation between a native species and an introduced exotic of the same genus (i.e., congeners), hybridisation between two exotics, and the breeding, introduction and subsequent spread of hybrids. Consequences of different pathways may range from a local reduction in genetic diversity through to stable hybrids with greater vigour, environmental tolerance and pest resistance. The latter may expand their density and range at the expense of existing natives (Vila et al. 2000). Factors promoting the formation of hybrids include human introductions of non-local congeners, habitat disturbance and fragmentation increasing pollinator contact between congeners, overlap in flowering periods and pollination compatibilities (Vila et al. 2000). In Australia, hybridisation is known to occur between *Grevillea* species, such as *G. rosmarinifolia* × *G. lavandulacea* hybrids occasional throughout the southern Mt Lofty Ranges (Carr 1995, Robertson 1999, M. O'Leary pers. comm.). Ellis et al. (1991) found the likelihood of successful hybridisation between *Eucalyptus* species decreased with taxonomic distance.

## SOURCES OF ENVIRONMENTAL WEEDS

An analysis of weed incursions in the past 25 years (Groves and Hosking 1996) found that 58% of these 'escaped' after their deliberate, legal introduction for use in horticulture and agriculture. Randall (2001) listed 958 species of invasive and potentially invasive garden plants in Australia. Often species will be in cultivation for decades before being recorded as being naturalised (i.e., having formed a self-sustaining population). Naturalised populations can also remain small for years to decades, before undergoing a phase of rapid spread. The likelihood that a plant species will naturalise increases with the frequency of its planting (Mulvaney 2001). This will increase the probability that a species will encounter suitable conditions for spread, through wide introduction across the landscape and exposure to a range of climatic conditions over time. Mulvaney (2001) also found for the Adelaide region that planting amongst patches of indigenous vegetation appeared to increase the likelihood of naturalisation.

## MANAGEMENT OF ENVIRONMENTAL WEEDS IN SOUTH AUSTRALIA

The control of environmental weeds threatening native vegetation in South Australia (SA) is undertaken by private landholders, volunteers (e.g., Friends of Parks groups, Bush for Life groups, Recovery Teams), weed control and bush regeneration contractors, state government agency landholders (e.g., NPs and Wildlife Service, ForestrySA, SA Water) and local governments. Funding (both private and government) for such control is limited. The focus to date has mainly been on multi-species weed control in specific reserves and/or threatened flora and habitats, rather than regional management of key weeds. Occasionally, significant government funds are available (at the Local, State and Commonwealth levels) to supplement large-scale control works. However, the geographic scale of the problem is often much greater than the funds available to tackle it. Some environmental weeds are proclaimed plants in SA under the Animal and Plant Control (Agricultural Protection and Other Purposes) Act, 1986. This means that landholders have a legal obligation to control the weeds and to minimise their spread. It does not mean that funds are then available to assist in control of the proclaimed plants, other than through advice and coordination through local Animal and Plant Control Boards.

Whilst there are high biodiversity gains from undertaking environmental weed control, a major disincentive is little (if any) short-term economic profit from doing so. Control can be expensive compared to agricultural weed control as some environmental weeds are difficult to kill using standard techniques, and off-target impacts on native vegetation must be minimised. Some species also develop long-lived soil seedbanks so control is long-term. The main financial motivation for environmental weed control is to avoid an even higher future cost if such works are delayed. As environmental weeds spread the cost of control increases exponentially, as does the likelihood of irreparable damage to the invaded habitat (Harris et al. 2001).

With limited resources for managing environmental weeds, the most cost-effective action is prevention of new weed threats through limits on cultivation of high weed risk species and early control of new weed incursions. Prevention and early intervention are key principles in the National and SA Weeds Strategies (ARMCANZ et al. 1997, Weed Strategy Committee 1998).

### ***Revegetation/Farm Forestry and Weed Risk***

The wide scale planting of species for revegetation, forestry, agriculture and horticulture increases the likelihood that some species will naturalise and invade native vegetation or other landuse systems. However, the majority will be of negligible weed risk; Williamson and Fitter (1996) estimated that around ten percent of naturalised plant species become weeds of significant economic and ecological impact. Concerns about the environmental weed risk of species promoted for revegetation and farm forestry had been raised by various SA organisations including the State Revegetation Committee, Trees for Life Inc., the Nature Conservation Society Inc., the Animal and Plant Control Commission (APCC) and within the PIRSA Revegetation Program. Various regional revegetation strategies recognise the weed risks of such species as tagasaste (*Chamaecytisus palmensis*) and pines, and have simple recommendations on reducing the risk of spread. In 2000, the PIRSA Environmental Weeds Working Group was convened and a recommendation of the Group's review of PIRSA's relevant activities was to formally analyse the weed risk of species being used for revegetation and farm forestry. A similar recommendation was listed in the SA Weed Strategy (Weed Strategy Committee, 1998).

In 2001 the PIRSA Revegetation Program and the State Revegetation Committee of SA commissioned the APCC to undertake an environmental weed risk assessment of 20 plant species. The species have been or are currently being used in SA for forestry, farm revegetation (e.g., for shelterbelts, dryland salinity management, soil stabilisation), amenity or for fodder/pasture. The list (AIM, Table 1) consisted of ten trees, five shrubs, one perennial herb and four grasses.

## **Weed Risk Assessment to Prioritise Weed Threats**

Weed risk assessment (WRA) is the use of standard, technical criteria to determine the relative weed threats posed by plant species. WRA aims to provide an objective and transparent decision tools for use in determining which plants may become weeds, or which weeds are priorities for control programs.

### **THE APCC WEED ASSESSMENT SCORESHEET**

The APCC has developed a system to rank the potential weed importance of plant species in different landuses. The APCC Weed Assessment Scoresheet (Virtue 2002) is based on a draft ranking system developed to determine weeds of national significance in Australia (Virtue et al. 2001). It has three main assessment criteria; invasiveness, impacts and potential distribution.

**Invasiveness** is used as an indicator of a weed's rate of spread. Faster spreading weeds are considered more urgent for control and thus of higher priority. A score for invasiveness is calculated from five multiple choice questions, relating to a weed's establishment ability, tolerance to routine weed control, reproductive ability and dispersal by natural and human-influenced means.

The **Impacts** criteria relates to the economic, environmental and social effects of weeds. The APCC system has six multiple choice questions for impacts, covering the weed's effects on establishment and growth of desired plants, reductions in product quality, effects on animal and human health, limits on physical movement, and effects on environmental health. Hybridisation risk is not considered in the APCC system.

**Potential distribution** considers the area at risk of invasion by the weed. This is best determined from a GIS analysis of climatic and soil preferences, overlaid with the locations of susceptible landuses/ecosystems.

Scores for Invasiveness, Impacts and Potential Distribution (each ranging from 0 to 10) are multiplied to give a **Weed Importance Score**. This is a relative score (ranging between 0 and 1000) that needs to be compared between species to determine priorities. Weeds are assessed separately for various landuses (e.g., aquatic, crop/pasture rotation, forestry, native vegetation, urban), so that the most important weeds of different landuses can be identified. The system is designed as a Microsoft Excel spreadsheet and has an explanatory guide (Appendix A). In this report weed risk is assessed for the native vegetation landuse.

### **DETERMINING WHICH SPECIES TO PLANT**

There are four criteria that need to be considered at the local level in selecting species for revegetation or farm forestry purposes:

1. Weed risk. This report's key focus is the environmental weed risk of the 20 species listed in Table 1 (see Aim).
2. Conservation value of local native vegetation. This involves considering what quality of native vegetation is at risk within the vicinity of a proposed revegetation or farm forestry planting. This includes considering whether the native vegetation is pristine or degraded, its conservation status (e.g., threatened/rare species and communities, reservation status) and the total area at risk.
3. Species utility/profitability. Revegetation and farm forestry species uses include salinity control, pasture/fodder, timber, firewood, windbreaks, carbon sequestration, soil stabilisation, wildlife habitat and amenity. Such uses can provide significant economic and/or environmental benefits. Species vary in their suitability for such uses. Major considerations are potential profitability, growth rates and survival.
4. Feasibility of control. This includes considering how easy it is to limit seed dispersal and control unwanted seedlings, and whether the species is already widely naturalised as a weed in the region.

Consideration of all of the above is needed to determine on a local scale whether a species (a) should not be planted, (b) could be planted with specific risk management guidelines to minimise spread, or (c) is simply safe for planting.

## AIM

This report aims to rank the environmental weed risk of the 20 species listed in Table 1.

*Medicago sativa* and *Themeda triandra* were specifically included to check the outcomes of the risk assessment process. It was generally thought that these two species did not pose significant environmental weed risks (*T. triandra* in particular as it is indigenous to much of SA). Assessments were done on a regional basis (see METHODOLOGY, Figure 1), using former NHT regions. It is recognised that there are considerable environmental differences within some of these regions. However, the regions used approximate the boundaries of the natural resource management groups forming across SA, at which planning and policy decisions will be made.

There are often several common names for plants. This can cause confusion in identity. Thus for clarity (and brevity) the species will be referred to by their scientific name in the remainder of this report (mainly using Shepherd et al. 2001).

**Table 1. Scientific and common names of the twenty species assessed.**

Life form	Scientific name	Common name/s
Trees:	<i>Casuarina glauca</i>	Swamp oak
	<i>Eucalyptus cladocalyx</i>	Sugar gum
	<i>Eucalyptus globulus</i> ssp. <i>globulus</i>	Tasmanian blue gum
	<i>Eucalyptus grandis</i>	Flooded gum
	<i>Eucalyptus occidentalis</i>	Flat-topped yate
	<i>Eucalyptus platypus</i>	Round leaf moort
	<i>Eucalyptus saligna</i>	Sydney blue gum
	<i>Pinus brutia</i>	Calabrian pine, Turkish pine
	<i>Pinus halepensis</i>	Aleppo pine
Shrubs:	<i>Pinus radiata</i>	Radiata pine
	<i>Acacia cyclops</i>	Western coastal wattle
	<i>Acacia saligna</i>	Golden wreath wattle
	<i>Atriplex amnicola</i>	River saltbush
	<i>Atriplex nummularia</i> ssp. <i>nummularia</i>	Old man saltbush
Perennial herb:	<i>Chamaecytisus palmensis</i>	Tagasaste, Tree lucerne
<i>Medicago sativa</i> ssp. <i>sativa</i>	Lucerne	
Grasses:	<i>Ehrharta calycina</i>	Perennial veldt grass
	<i>Puccinellia ciliata</i>	Puccinellia
	<i>Themeda triandra</i>	Kangaroo grass
	<i>Thinopyrum ponticum</i>	Tall wheatgrass

## **METHODOLOGY**

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The following steps were undertaken for the 20 species listed in Table 1.

### ***Information Sources***

#### **HERBARIUM DATA**

Locations where species have been recorded as naturalised in SA were obtained from the database of the State Herbarium of SA. Records of the locations of cultivated or planted individuals were investigated for notes regarding any dispersal from the original planting(s). Point locations where any species had naturalised were used in the climate matching analysis and included on the distribution maps.

#### **SURVEYING PEOPLE**

A request for information regarding observations of the naturalisation and impacts of any of the 20 species was distributed by email, post and articles in newsletters to people involved in revegetation, management of native vegetation and/or weed control. Approximately 150 responses were received, reflecting a significant level of concern about the issue in SA.

#### **LITERATURE REVIEW**

A review of published literature (scientific journals, books, reports) was undertaken for each species for information on biology, ecology, weediness in other places and climate matching. Internet searches were also performed, focusing on international herbaria sites and plant databases.

#### **FIELD OBSERVATIONS**

Fieldtrips were undertaken to the Lower and Upper South-East, Adelaide Hills, Barossa, Lower and Upper Eyre Peninsula, Yorke Peninsula, Kangaroo Island, Fleurieu Peninsula and Mid-North regions of SA. The fieldtrips involved meetings, interviews and site visits. Site assessments for invasiveness and impacts were based on simple observations and judgements regarding the biomass, plant density and percentage cover of the species in question and its effects on the surrounding native vegetation. Detailed scientific measurements could not be undertaken within the timeframe of this project.

More than 50 plant specimens were collected during field trips and have been submitted to the State Herbarium of SA for inclusion in the herbarium collection. GPS locations of naturalised populations of the 20 species in question were also used on the distribution maps.

## **Weed Risk Assessments**

### **SPECIES PROFILES AND SCORING**

Information gained from the above processes was used to analyse the potential weed risk of each species. A profile was written based around the questions in the APCC Weed Assessment Scoresheet (see Appendix 1) and species were then scored. The species were scored for the Native Vegetation landuse, where the desired vegetation is the local native plant species. The second invasiveness question on the species' tolerance to average weed management practices in the landuse was always answered as "very high", as it was assumed that on a regional scale there is negligible routine weed control in native vegetation. It was also assumed that fire was only a rare event and that there was low grazing pressure, both being a consequence of the fragmented nature of most of the remaining native vegetation in SA. Hybridisation risk was not considered in the assessment process, as the focus was on the species itself behaving as an environmental weed.

### **GIS ANALYSIS FOR DETERMINING POTENTIAL DISTRIBUTIONS**

The proportion of native vegetation suited to the naturalisation of a species (for determining the potential distribution score) was determined in ArcView GIS as follows:

- CLIMATE (Pheloung 1996) was used to predict the potential distribution of each plant species, based on temperature and rainfall parameters. A climatic profile was generated based on the species' international geographic distribution (its native range and/or where it has naturalised), including within Australia. This was matched to a climate surface model of Australia, on a 0.5 × 0.5 degree grid basis. The grid was then converted to polygons within SA.
- SA was divided into seven regions based on NHT regions (Figure 1):
  1. Rangeland / Aboriginal Lands (Range/AL)
  2. Eyre Peninsula (Eyre)
  3. Northern Agricultural Districts, including Yorke Peninsula (NAD)
  4. Mt Lofty Ranges / Adelaide Metropolitan (MLR/Metro)
  5. Kangaroo Island (KI)
  6. Murray Darling Basin (MDB)
  7. South-East (SE)
- Soil attribute GIS data was obtained from PIRSA Land Information for the southern regions (all except Range/AL). The Atlas of Australian Soils GIS data was used for Range/AL region. Key soil attributes identified as limiting for certain species were used to determine areas with suitable soils.
- Native vegetation GIS data (August 2001) was obtained from the Department of Environment and Heritage. This data did not categorise the vegetation types. The Range/AL region was treated as all being native vegetation (excluding lakes),



although it is recognised that this includes pastoral leases. Figure 2 shows the areas considered as native vegetation in SA.

- The native vegetation polygons were cut according to the seven regions, and then split according to soil attribute polygons.
- Areas of native vegetation with potential for invasion by a species were determined by selecting polygons of native vegetation (split for soils) that were firstly within a high climate match, and secondly within an area with suitable soil attributes.
- The total areas of native vegetation at risk within each region were calculated in square metres in a Lamberts Conformal Conic GDA94 projection. These were then calculated as the percentage of total native vegetation at risk within each region.

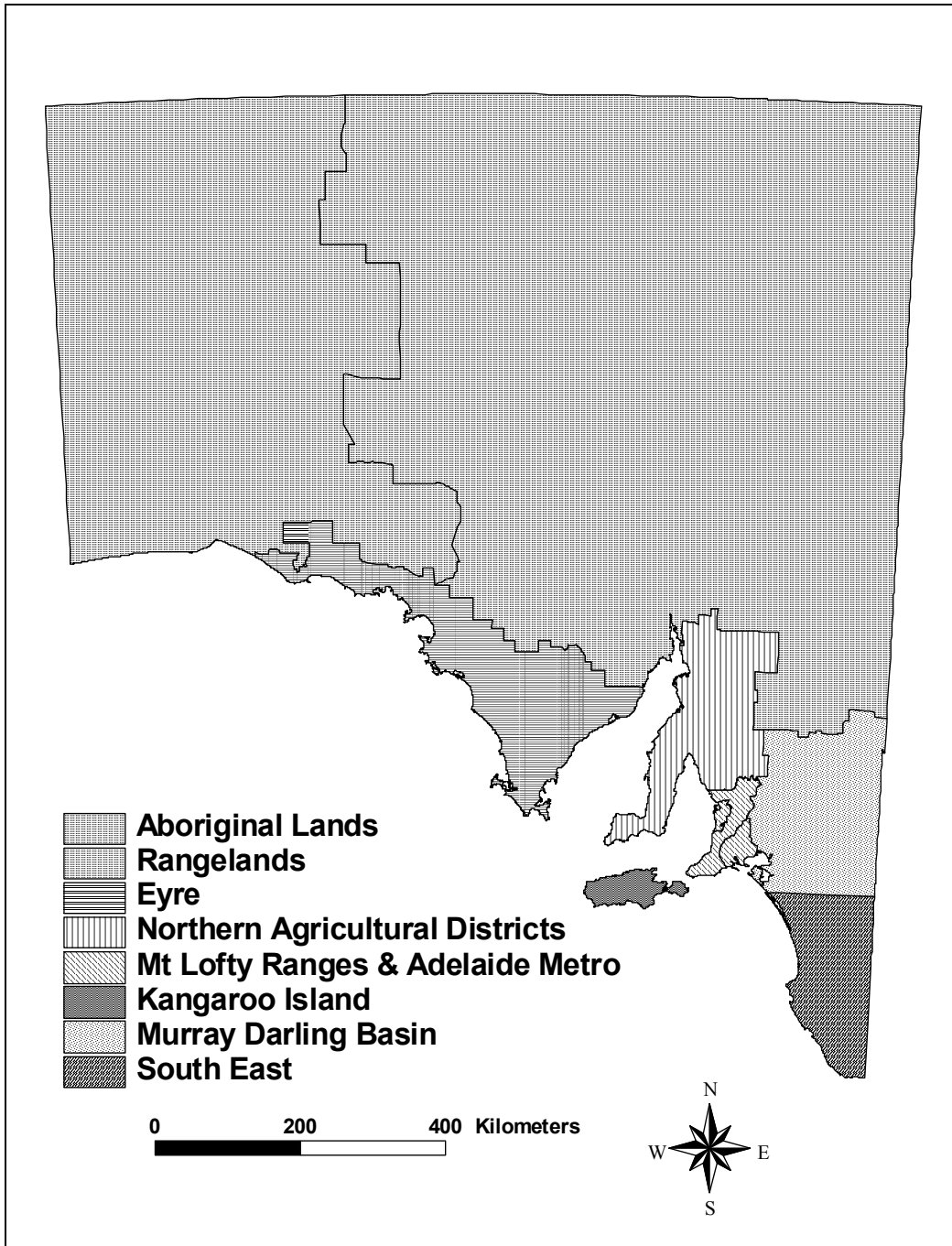
Two errors are known with the GIS data used. Hindmarsh Island and other offshore islands were excluded, as these were not in the NHT region shapefiles. A small, north-west portion of the Eyre region is also excluded, as this was not covered in the PIRSA Land Information Soil Attributes data.

The Potential Distribution scoring in the APCC Weed Assessment Scoresheet (Virtue 2002 and Appendix 1) had been conservative in that choices were limited to the nearest twenty percent and scores reflected the higher end of the range (e.g., 20-40% range scores 4). With the use of GIS analysis in this project the scoring was adjusted to round to the nearest ten percent (e.g., 15-24% range scores 2, 25-34% range scores 3, 35-44% range scores 4). The exception is percentage of native vegetation at risk in the range of 1-7.5%, which was scored as 0.5).

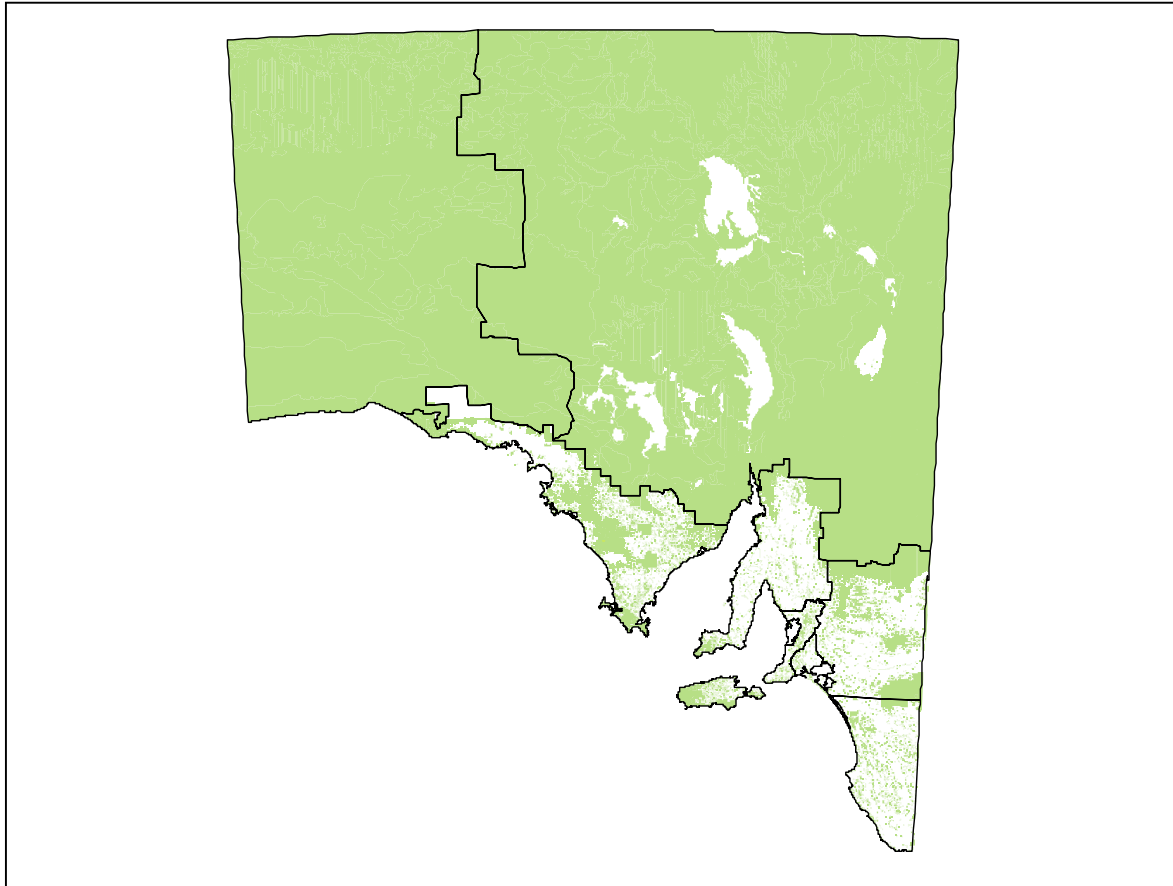
## **POTENTIAL DISTRIBUTION SCORING FOR INDIGENOUS SPECIES**

A difficulty arose when considering species that were indigenous to parts of SA. Such species cannot be considered to be newly invading weeds of native vegetation in the regions to which they are indigenous. However, an introduction of a non-indigenous form of the species from another region could be considered a new invader if this genotype had some competitive advantage over indigenous forms. Such introductions could also lead to genetic crossing between indigenous and non-indigenous forms of a species, with possible detrimental impacts on the local genetic diversity of the species. An indigenous species may also increase in density due to some environmental change, to the detriment of other native plants.

Whilst acknowledging the above concerns, it was decided that scoring for the Potential Distribution criteria would exclude areas where a species was indigenous. The report's focus is at the species level. In addition, use of local native species for revegetation where possible is becoming widely accepted as standard practice. Hence where a species was indigenous to a particular region then it would get a Potential Distribution score of "0" for that region.



**Figure 1. The seven regions used in the report. The regions are Rangeland / Aboriginal Lands, Eyre, Northern Agricultural Districts (including Yorke Peninsula), Mt Lofty Ranges / Adelaide Metropolitan, Kangaroo Island, Murray Darling Basin and South-East**



**Figure 2. Areas considered as native vegetation in SA (GIS data from Dept. of Environment and Heritage and PIRSA).**

### **COMPARING SPECIES**

Species were grouped into trees, shrubs/herbs and grasses, and initially compared across the six regions in southern SA (i.e. excluding the Rangeland/Aboriginal Lands region due to its high total area of native vegetation). Proclaimed plants that had been previously scored by APCC for their weed risk in native vegetation were included for reference. Weed Importance scores were also calculated for species for each region using regional potential distribution scores (invasiveness and impacts scores unchanged).

Species were classed as very high, high, medium, low and negligible weed risk based on their Weed Importance Score (Table 2). The cut-off scores are based on 20% percentile bands for all possible scores, as explained in Appendix 1.

**Table 2. Weed risk classifications.**

<b>Weed Importance Score</b>	<b>Weed Risk Classification</b>
209+	Very High
<209	High
<84	Medium
<29	Low
<3	Negligible

### ***Draft Report Circulation***

The draft report was circulated for comments and corrections to key organisations and individuals who had contributed to its development (see Acknowledgements). Twenty written submissions were received from individuals and organisations (State Herbarium of SA, Department of Environment and Heritage, ForestrySA, Urban Forest Biodiversity Program, Nature Conservation Society of SA Inc. and Threatened Species Network). Comments and additional information were integrated into the final draft.

## RESULTS: TREES

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**Photo 1.** *Eucalyptus cladocalyx* seedlings in the Adelaide foothills, near Burnside. (Photo R. Melland)



**Photo 2.** *Pinus radiata* seedlings in remnant bushland in the South-East, near Mt Gambier. (Photo J. Virtue)



**Photo 3.** *Pinus halepensis* seedlings in remnant bushland on a Yorke Peninsula roadside. (Photo R. Melland)



**Photo 4.** *Casuarina glauca* thicket in the central Eyre Peninsula, near Lock. (Photo R. Melland)

## ***Casuarina glauca* Sieber ex Spreng. (Casuarinaceae)**

### **Swamp oak**

#### **PLANT DESCRIPTION**

*Casuarina glauca* is a suckering tree reaching a height of approximately 8-20 m high (Wilson and Johnson 1989). *C. glauca* (from eastern Australia) and *C. obesa* (from central and western Australia) are very similar in appearance. *C. glauca* has teeth on new stem tips which recurve back, whilst the teeth of *C. obesa* appear straighter (Johnson and Wilson 1986). *C. obesa* is generally thought of as the non-suckering form of *C. glauca*, however suckering forms of *C. obesa* have been found in SA (H. Smyth pers. comm.).

#### **HISTORY OF USE IN SA**

*C. glauca* has been in cultivation in SA since the early 1900s (Mulvaney 1991). The species has been used for farm windbreaks and shelter, farm and roadside amenity plantings, and for dryland salinity control. It has been widely planted across the agricultural zone of SA.

#### **ORIGINS**

*C. glauca* originates from the coast of eastern Australia, ranging from central Queensland to southern New South Wales (NSW). The species “grows in brackish situations along estuaries and streams, usually near the coast.....often forming pure stands as an open forest or woodland”. (Wilson and Johnson 1989)

#### **INVASIVENESS**

##### **Naturalisation history**

Within SA. *C. glauca* was not listed in the 1993 edition of Vascular Plants of SA (Jessop 1993). However, there are herbarium records, submitted since 1993, of thickets spreading from plantings in the Flinders Ranges (Quorn), Northern Lofty (Tarlee, Riverton) and Southern Lofty (Hindmarsh Island, Strathalbyn, St Kilda) botanical regions. Personal observations of spread from planted trees (principally by suckering) within SA include:

*Eyre Peninsula* – Elliston district with a large infestation at Polda Homestead (B. Napier pers. comm., authors), Boston Island (S. Bey pers. comm.), Koppio hills (D. Ancell pers. comm.) and Port Lincoln (authors);

*Yorke Peninsula* – Maitland-Winulta and Minlaton-Stansbury roadsides (H. Longbottom pers. comm.);

*Mid North* – Clare-Farrell Flat and Spalding-Gulnare roadsides (H. Longbottom pers. comm.);

*Adelaide Metropolitan and Hills* – Monarto (J. Bollard pers. comm.), Belair National Park (NP) and Watiparinga Reserve (E. Robertson pers. comm.), Brownhill Creek

Recreation Park (M. Lane pers. comm.), Mt Barker (A. Crompton pers. comm.), and Joe Gappa Reserve, Hillbank (P. Tucker pers. comm.). Threatening coastal samphire habitat near the Little Para Estuary (K. Mercer pers. comm.);

*Fleurieu* – Onkaparinga Gorge and estuary (R. Chapman pers. comm.);

*Kangaroo Island* – Dudley Peninsula (author), outskirts of Brownlow and Kingscote and Cygnet River estuary (B. Overton pers. comm.);

*Murray Mallee* – Murray Bridge (authors); and

*Upper South East* – Bordertown to Pinaroo roadside (G. Cotton pers. comm.).

Figure 3 shows reported locations of naturalised *C. glauca* in SA.

Within Australia. *C. glauca* has spread from plantings at Nedlands, Western Australia (Hussey et al. 1997).

Internationally. *C. glauca* is a serious invader of swamps in Florida, USA (McCann et al. 1996).

### **Establishment**

In SA *C. glauca* has been observed to spread primarily by suckering, with seedlings being very rare (B. Bartel, J. Bollard pers. comm.). Seedlings were reported in wetlands at St Kilda and a watercourse at Riverton (State Herbarium SA records). Establishment by suckering is vigorous due to access to resources from the parent tree. This would enable establishment in dense vegetation.

### **Reproduction**

*C. glauca* produces an average of 70 seeds per cone (El-Lakany et al. 1989), each weighing around 2-5 mg (ATSC 2001). Seed is held in cones until the death of branches/trees (e.g., following fire). Thus whilst seed will accumulate in the crown, annual seed rain is likely to be much less than 1000 seeds/m<sup>2</sup>. Time to seed production for new suckers is likely to be >3 years, given competition from older suckers.

Suckering by *C. glauca* leads to dense circular thickets around the original parent tree. The parent tree will eventually be surrounded by maturing suckers, which in turn will produce their own suckers. Competition for space and light will then limit new suckers borne from the original tree. Given this competition, the rate of vegetative reproduction per mature stem is probably slow.

### **Dispersal**

With negligible observations on *C. glauca* establishment some distance from plantings in SA, long-distance seed dispersal appears to be an unlikely event. *C. glauca* seed are winged and a few seeds would probably be wind-dispersed >100 m as cones open after a fire. However, fire is an infrequent event, and in its absence *C. glauca* does not spread by seed in a similar fashion to, for example, *Pinus halepensis*. Dispersal by suckering is only a few metres per year. Occasional spread along watercourses would probably occur, through movement of root pieces in flooding events, or cone bearing branches which would release seeds upon drying.

## IMPACTS

### Density

*C. glauca* forms dense thickets on a variety of soil types and spreads into adjacent native vegetation. Whilst its rate of spread is slow, it does have the potential to reach a **high** density if uncontrolled. Grazing will control the rate of spread, but grazing pressure is assumed to be low on average in native vegetation. At a large infestation above the Poldas Basin on the Lock-Elliston road on Eyre Peninsula, no grazing had occurred for approximately 30 years. Thickets of 80-100 m diameter had formed from apparently 6-8 original trees each.

### Competitiveness

*C. glauca* thickets observed in SA had excluded most other vegetation, probably due to dense shading and competition for soil moisture. Leaf litter was also abundant, although it is not known if this has an allelopathic effect on other plants or whether it simply smothers them. Clark et al. (1996) found that coastal wetland forests dominated by *C. glauca* had very high annual litter fall rates in comparison to other Australian temperate and sub-tropical forests. Thus a high impact from this species is likely, on the establishment, biomass and diversity of local native plant species. Strong concerns were expressed about the potential impact of *C. glauca* spreading into remnant native vegetation (C. Potts and E. Kolak, N. Mallen, D. Symon, B. Bartel pers. comm.).

### Movement

Tall, dense thickets of most age classes of *C. glauca* substantially slow movement of animals and people, but are rarely impenetrable. Water movement through watercourses may be impeded (J. Edwards pers. comm.). *C. glauca* on roadsides also limits vision and vehicular access, with grading triggering suckering (L. Bebbington pers. comm.).

### Health risks

There are no health risks to humans or animals associated with *C. glauca*. The species is grazed by stock, although it has a relatively low palatability to sheep (Kaitho et al. 1996).

### Ecosystem health

The roots of *Casuarina* species nodulate profusely in association with *Frankia* bacteria to fix nitrogen, particularly in soils that are high in phosphorus (Bowen 1986). Clark et al. (1996) found that the areas underneath *C. glauca* forests are nutrient sinks and that flood events flush these nutrients into and along streams. Thus there is the possibility that *C. glauca* may significantly increase nitrogen levels, at least in riparian ecosystems.

*C. glauca* may pose a threat to non-saline groundwater and streamflow levels in dry areas. Cramer et al. (1999) found greater groundwater discharge rates in *C. glauca* compared to *Eucalyptus camaldulensis* and *Melaleuca halmaturorum*. However, the potentially negative effect of increased groundwater use may be offset by the ability of *C. glauca* to utilise saline groundwater without uptake and leaf excretion of salt (Fraser et al. 1996, Van der Moezel 1989). Thus its strategic use in the landscape (away from areas of native vegetation) may alleviate the risk posed by rising saline watertables to remnant native vegetation.



## POTENTIAL DISTRIBUTION

### Climate tolerances

A climate match for *C. glauca* was done based on its native distribution in NSW and Queensland (Australia's Virtual Herbarium [AVH] 2001), and the most extensive naturalised populations in SA (St Kilda, Riverton and Elliston). The match was based on temperature alone, assuming that establishment by suckering was more dependant on groundwater availability than rainfall. Boomsma (1983) stated it is suitable for most soils above 350 mm annual rainfall in SA.

### Soil tolerances

*C. glauca* persists in a wide range of soil types in SA. It grows particularly well in heavier clay soils (D. Symon pers. comm.) and tolerates saline, waterlogged soils. Watercourses and soils with a shallow water table are particularly at risk of vigorous spread from plantings of this species.

PIRSA Land Information soil attributes and classes selected for *C. glauca* were:

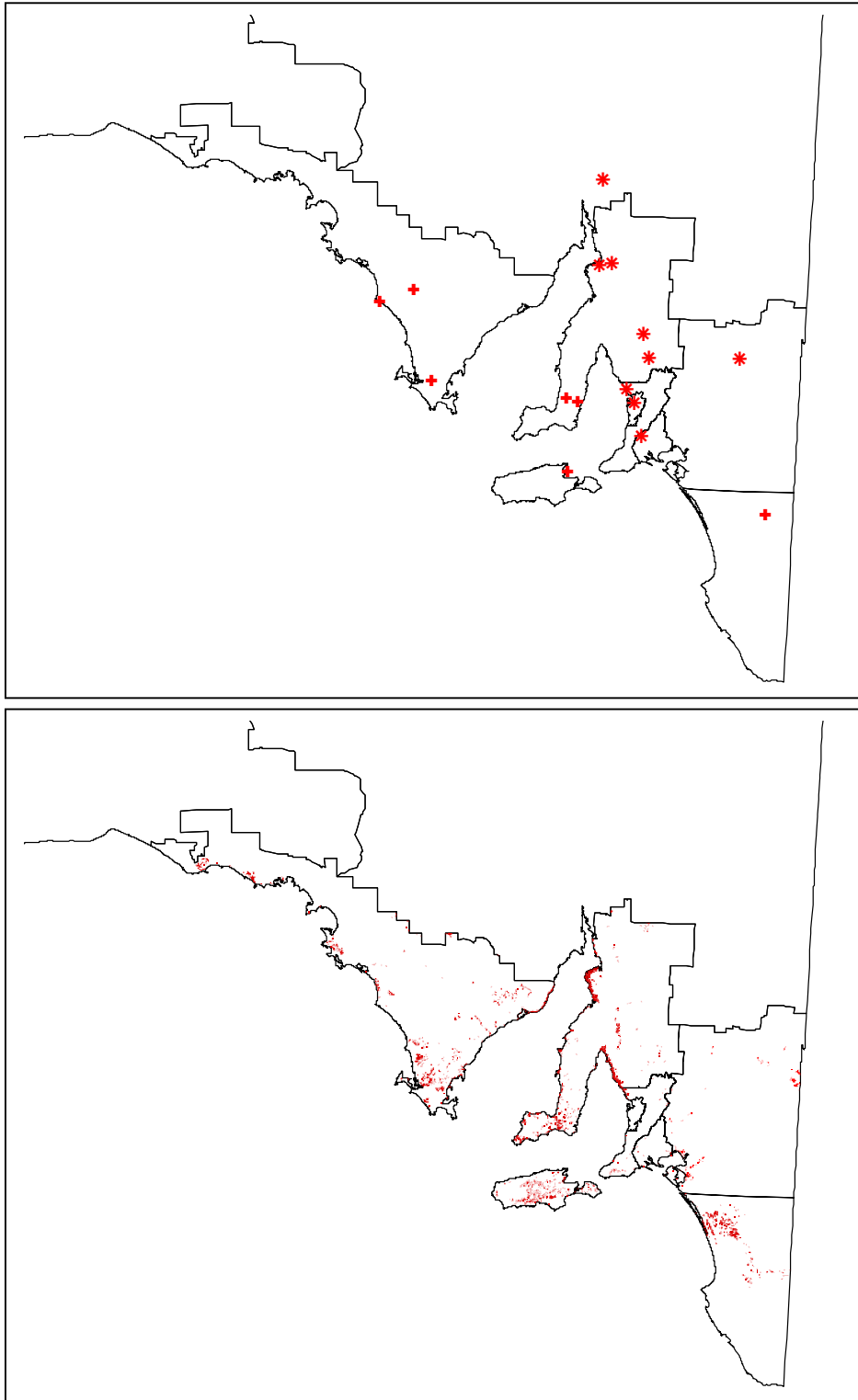
- Depth to Water Table: 200 cm to above surface for up to 3 months.

### Areas at risk

The areas and regional proportions of native vegetation in SA with potential for invasion by *C. glauca* are shown in Figure 3 and Table 3 respectively.

**Table 3. Regional proportions of native vegetation with potential for invasion by *Casuarina glauca*.**

Region	Proportion of native vegetation at risk
Eyre	4%
Northern Agricultural Districts	10%
Mt Lofty Ranges / Adelaide Metropolitan	4%
Kangaroo Island	8%
Murray Darling Basin	1%
South-East	10%
<i>Southern SA (all of above regions)</i>	5%
Rangeland / Aboriginal Lands	0%



**Figure 3. Known locations of naturalised *Casuarina glauca* (top) and areas of native vegetation with potential for invasion by the species in SA (bottom). Location symbols are: \* State Herbarium of SA records, + Authors records.**

## ***Eucalyptus cladocalyx* F.Muell. (Myrtaceae)**

### **Sugar gum**

#### **PLANT DESCRIPTION**

*Eucalyptus cladocalyx* is a medium to tall tree which grows to 15-35 m in its native range (Boomsma 1983).

#### **HISTORY OF USE IN SA**

*E. cladocalyx* is widely planted for farm windbreaks, amenity plantings, timber and firewood across SA. The state's Director of Forestry promoted the species in the early 1900s.

#### **ORIGINS**

*E. cladocalyx* is indigenous to the Flinders Ranges, southern Eyre Peninsula, Northern Lofty and Kangaroo Island regions of SA (Jessop 1986a).

#### **INVASIVENESS**

##### **Naturalisation history**

Within SA. *E. cladocalyx* has been observed to occasionally spread from plantings in the Eyre Peninsula, Yorke Peninsula, Adelaide Hills, Fleurieu Peninsula and the Upper South East regions. Personal observations of naturalisation of *E. cladocalyx* outside its current native range include:

*Yorke Peninsula* – Maitland roadside and native vegetation block (H. Longbottom pers. comm.);

*Adelaide Hills* – Morialta Conservation Park (CP) (P. Tucker pers. comm.), Burnside hillsface and Mt Barker summit (A. Crompton pers. comm.), Parra Wirra RP (D. Hughes pers. comm.), Belair NP, Brownhill Creek RP and Shepherds Hill RP (E. Robertson pers. comm.);

*Fleurieu* – Strathalbyn cemetery (N. Mallen pers. comm.) and Cox Scrub CP (Rosemary Chapman pers. comm.); and

*Upper South East* – Town reserve in Wolseley, near Bordertown (J. Samuel-White pers. comm.)

Figure 4 shows reported locations of *E. cladocalyx* in SA, categorised into indigenous and naturalised populations. The absence of seedlings from many old plantings should also be noted. For example, seed from the tallest, straightest form of the species was brought to the Eyre Peninsula approximately 60 to 80 years ago and no spread has been seen from these trees (H. Lamont pers. comm.). Similarly, there has rarely been spread from the

many plantings of *E. cladocalyx* on the Yorke Peninsula in the early 1900s (H. Longbottom pers. comm.).

Within Australia. *E. cladocalyx* had been widely planted in Victoria (Lazarides 1997), especially on plains country in the west of the state, as windbreaks and roadside plantings (Costermans 1981). The species has frequently naturalised in a range of vegetation types in Victoria, but populations are very small and localised (Carr et al. 1992).

Internationally. *E. cladocalyx* has widely naturalised in native vegetation in southern South Africa (Henderson 1995). The species has also naturalised in southern California (Hickman 1996).

## **Establishment**

Germination of eucalypts is generally best on mineral soil (Jacobs 1961). Seeds do not form a long-lived soil seedbank. Recruitment is greatest after a hot fire, when seed is shed from dried, canopy-held capsules and falls onto an ash-bed.

In SA, *E. cladocalyx* has been observed to establish in *E. leucoxylon* (SA blue gum) and sheoak (e.g., *Allocasuarina verticillata*) woodlands (N. Mallen pers. comm.) and amongst various open vegetation types on roadsides adjacent to original plantings. In Victoria, *E. cladocalyx* has established in grasslands, woodlands, dry sclerophyll forest, riparian vegetation and rocky outcrop vegetation (Carr et al. 1992). In South Africa, *E. cladocalyx* has naturalised in heath (i.e. fynbos), forest gaps and watercourses (Henderson 1995). Establishment is greater at disturbed or moderately disturbed sites such as roadsides (G. Carr pers. comm.).

The range of vegetation types invaded by *E. cladocalyx* (in SA and elsewhere) indicates a quite vigorous establishment ability in mediterranean climates in comparison to other eucalypts.

## **Reproduction**

Individual eucalypt fruits (capsules) usually have 2-10 viable seeds, with the remaining contents shed from fruits being non-fertile chaff (Turnbull and Doran 1987). Eucalypt seed is usually retained until a fruit dies and dries out. Timing of seed shedding may range from several months to several years after maturity (Turnbull and Doran 1987). Seed rain is likely to be less than 1000 seeds/m<sup>2</sup>/year.

*E. cladocalyx* ranges from being self-compatible to self-incompatible, with the self-pollinated trees producing fewer capsules and fewer seeds per capsule (Ellis and Sedgley 1992). At field sites it was often observed that seedlings were only produced by a minority of the planted trees present.

## **Dispersal**

Seed dispersal is limited in the *Eucalyptus* genus (Potts and Reid 1988), with wind being the key agent of dispersal of the seeds (Turnbull and Doran 1987). Cremer (1977) found that 12 of 15 species of *Eucalyptus* with wingless seeds dispersed less than 30 m from the parent tree when released at 40 m above the ground into a wind speed of 10 km/h. He concluded that few seeds are dispersed greater than twice the height of the tree.

*E. cladocalyx* seeds are not winged. Seedlings were generally seen within 30 m of the parent tree's trunk, with rare seedlings beyond that depending on the prevailing winds.

## IMPACTS

### Density

*E. cladocalyx* has been found to slowly spread into native vegetation from plantings in SA and elsewhere, particularly into open vegetation types (e.g., grasslands) and vegetation subject to natural disturbance (e.g., riparian areas). Being indigenous to various parts of the state, the species is well-adapted to the SA climate. For these reasons we suggest it could achieve a **medium** density in the long-term if allowed to spread from plantings into native vegetation.

The highest density observed for this species was in 'Gully Reserve', Burnside, where hundreds of saplings of various age classes had covered 2 ha adjacent to trees planted along a fence line in the early 1900s. However, the area had a history of clearing and grazing, so the past removal of competing native woody vegetation must be considered when assessing the high density of *E. cladocalyx* at this site. At other locations in the Adelaide hills, Upper South-East and Yorke Peninsula the species has spread in significantly lower densities than at the Burnside locality.

### Competitiveness

Whilst *E. cladocalyx* is likely to achieve a higher density in native vegetation in southern SA in comparison to the other eucalypts considered in this project, its competitive effects still appear to be less than other invasive trees such as pines or olives. *E. cladocalyx* provides a similar vegetation structure to other local eucalypts such as *E. leucoxyton* and *E. viminalis*, with a relatively open understorey and a tall, intermediately-dense overstorey. Within plantings and amongst spreading *E. cladocalyx* there were moderate densities of native grasses and shrubs. At Strathalbyn cemetery, the plantation of *E. cladocalyx* had an understorey of native apricot (*Pittosporum phylliraeoides*) ruby saltbush (*Enchylaena* sp.), Vittadinia daisy (*Vittadinia* sp.), flax lily (*Dianella* sp.) and native grass (*Austrostipa elegantissima*) (N. Mallen pers. comm. & pers. obs.). At Burnside, there were more native grasses and fewer woody weeds (e.g., boneseed (*Chrysanthemoides monilifera* ssp. *monilifera*), blackberry (*Rubus fruticosus* agg.), hawthorn (*Crataegus monogyna*)) amongst the *E. cladocalyx* than in the adjacent open areas. In indigenous, old growth forests of *E. cladocalyx* (e.g., at Flinders Chase on Kangaroo Island, Dutchmen's Stern near Quorn in the Flinders Ranges, and in hills near Port Lincoln) the understorey flora can be quite sparse with scattered shrubs and monocots (M. O'Leary pers. comm.). Thus *E. cladocalyx* may reduce the establishment and growth of local native species to a small extent, particularly large shrubs and trees.

### Movement

*E. cladocalyx* may impede some physical movement of people or animals during the early stages of seedling regeneration, particularly in close proximity to parent trees. However, seedlings would thin out (in competition with themselves and other woody natives) and become tall with a straight trunk. In that respect *E. cladocalyx* would not significantly alter movement from that which is possible in the majority of woodland and forest vegetation types in SA.

## Health risks

*E. cladocalyx* can have toxic foliage, particularly juvenile foliage which can contain up to 20% of leaf nitrogen as cyanogenic glycoside (Gleadow and Woodrow 2000). *E. cladocalyx* foliage has caused cyanide poisoning in goats, where grazing on a felled-tree caused 24 deaths in a herd of 50 (Webber et al. 1995). Deaths have also been recorded in sheep, after eating leaves lopped for drought feeding or on new sucker shoots after the lopping of trees (Everist 1974). Despite these deaths, in native vegetation the toxicity of *E. cladocalyx* is unlikely to be of significant impact. *E. cladocalyx* already exists as natural stands throughout SA so there may be some level of tolerance or avoidance by native fauna, at least in those regions. People are not going to consume the foliage.

## Ecosystem health

*E. cladocalyx* is unlikely to significantly change ecosystem processes in comparison to locally-indigenous *Eucalyptus* spp., particularly if it will only achieve a medium to low density.

## POTENTIAL DISTRIBUTION

### Climate tolerances

A climate match for *E. cladocalyx* was done based on its native distribution in SA (Specht 1972), and naturalised distribution in SA, Victoria (pers. obs. and AVH 2001) and South Africa (Henderson 1995). This indicated that *E. cladocalyx* is widely suited to the agricultural zone of southern SA.

### Soil tolerances

In its native distribution in SA, *E. cladocalyx* grows on yellow and lateritic podzolic soils (neutral to acidic, duplex soils on lower Eyre Peninsula and in the Southern Flinders Ranges) and on skeletal soils (shallow, grey-brown, sandy soil on Kangaroo Island) (Specht 1972). *E. cladocalyx* grows best on acid-neutral soils, but will tolerate low levels of lime (Boomsma 1983). At Strathalbyn cemetery trees were establishing on shallow soils over limestone. At Wolseley and in parts of Victoria (G. Carr pers. comm.) trees have established on cracking clay soil. These observations, plus widespread successful planting of *E. cladocalyx* on farms suggests that it has a very wide soil tolerance, and that some other factor limits its natural distribution in SA.

Based on locations of indigenous populations of *E. cladocalyx* in SA, the following PIRSA Land Information Most Common Soil Groups were selected for southern SA:

- Sand over clay soils
- Deep loamy texture contrast soils with brown or dark subsoils
- Shallow to moderately deep acidic soils on rock
- Shallow soils on rock

Shallow calcareous/non-calcareous loamy soils (map units BB, F, Fa and Fz) and brown calcareous earths (map unit DD) were selected from the Atlas of Australian Soils (Northcote et al. 1968) for *E. cladocalyx* in rangeland areas.

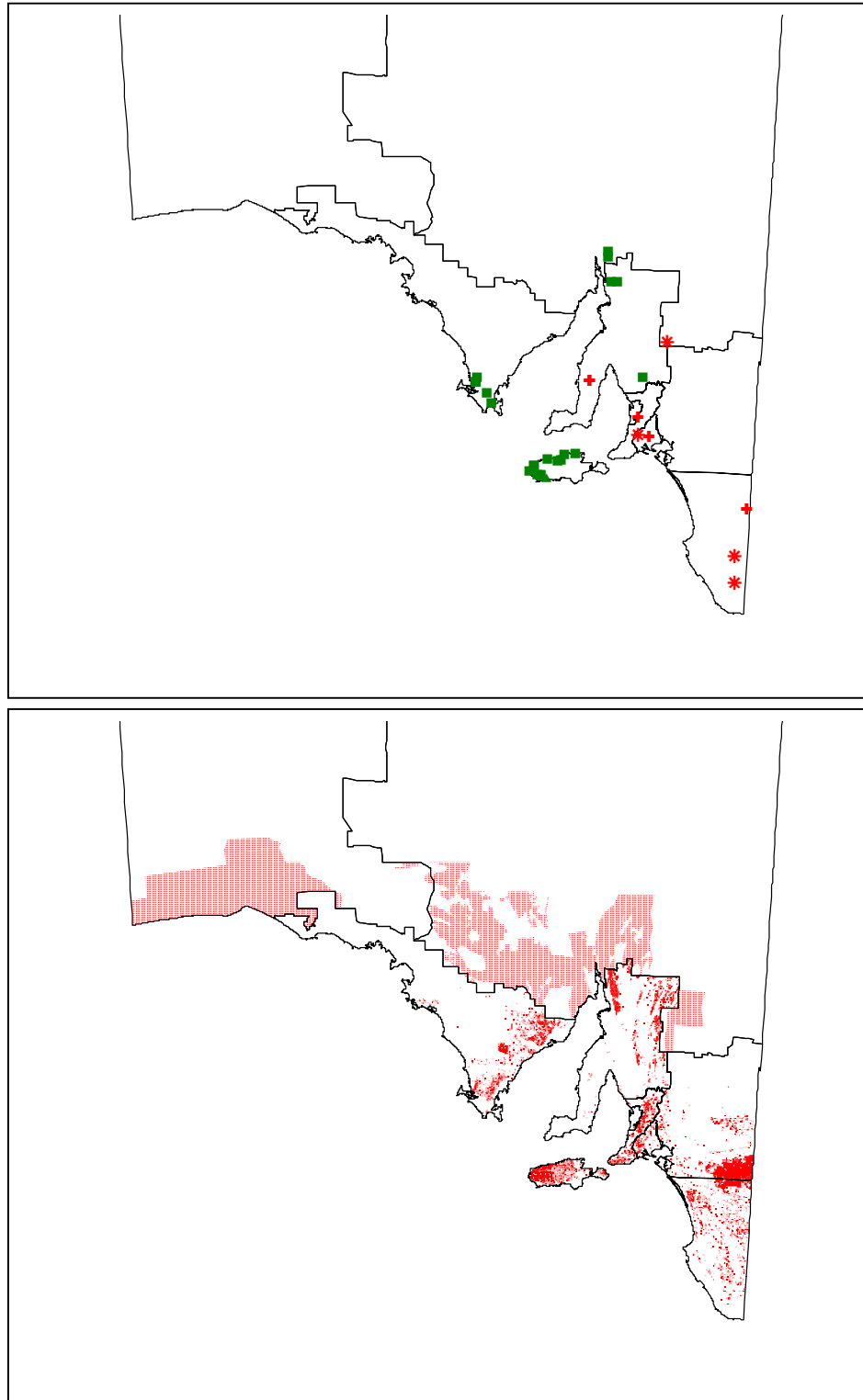
### Areas at risk

The areas and regional proportions of native vegetation in SA suitable for *E. cladocalyx* are shown in Figure 4 and Table 4 respectively. Note that *E. cladocalyx* is indigenous to the lower Eyre Peninsula, Northern Agricultural Districts/Flinders Ranges and Kangaroo Island and hence the species is not a potential invader in these regions.

In Figure 4 the potential distribution prediction for the Rangelands / Aboriginal Lands is probably overestimated and the Flinders Ranges region also needs to be discounted. The proportion suitable for *E. cladocalyx* is likely to be <5%.

**Table 4. Regional proportions of native vegetation suitable for *Eucalyptus cladocalyx*. Parentheses indicate the species is indigenous to the region and thus the Potential Distribution score becomes zero.**

Region	Proportion of native vegetation at risk
Eyre	(9%)
Northern Agricultural Districts	(29%)
Mt Lofty Ranges / Adelaide Metropolitan	86%
Kangaroo Island	(48%)
Murray Darling Basin	21%
South-East	54%
<i>Southern SA - all of above regions</i>	<i>(22%)</i>
<i>Southern SA - excluding indigenous regions</i>	<i>12%</i>
Rangeland / Aboriginal Lands	(10%)



**Figure 4.** Known locations of native and naturalised *Eucalyptus cladocalyx* (top) and areas of native vegetation suitable for the species in SA (bottom). Location symbols are: ■ State Herbarium of SA indigenous records, \* State Herbarium of SA naturalised records, + Authors naturalised records.



## ***Eucalyptus globulus* Labill. ssp. *globulus* (Myrtaceae)**

### **Tasmanian blue gum**

#### **PLANT DESCRIPTION**

*Eucalyptus globulus* is a tree which grows to 25-60 m in height in its native range (Costermans 1981).

#### **HISTORY OF USE IN SA**

*E. globulus* has been listed in SA garden catalogues since 1862 (Mulvaney 1991). Plantations of this species in the south-east of SA have been established since the mid 1980s. There has been an investor-driven boom in plantings in that region, as well as in neighbouring Victoria. Smaller-scale plantations have been established in the Mt Lofty Ranges in the last decade, with continuing government promotion of the potential for production in the region. *E. globulus* is used in Australia for timber, pulp, oils, and honey and as an ornamental tree (Lazarides et al. 1997).

#### **ORIGINS**

There are four sub-species of *Eucalyptus globulus* in Australia, one of which, *E. globulus* ssp. *bicostata*, is native to SA. This sub-species is found north of Burra in the Mid-North region, at Mt. Bryan. The other three sub-species (ssp. *globulus*, ssp. *psuedoglobulus* and ssp. *maidenii*) are native to southern and eastern Tasmania, the Ottways and Wilsons Promontory in Victoria, and to south-east NSW (AVH 2001, Costermans 1981).

Historic ornamental plantings and current forestry plantations have predominantly used *E. globulus* ssp. *globulus* originating from Tasmania.

#### **INVASIVENESS**

##### **Naturalisation history**

Within SA. *E. globulus* was not listed as naturalised in 1986 (Jessop 1986a). However, the species is listed for the Southern Lofty region in 1993 edition of Vascular Plants of SA (Jessop 1993). There are more recent herbarium records (submitted since 1993) for Kangaroo Island, Northern Mt Lofty Ranges and South-East SA (Figure 3.1.3). Personal observations of spread from planted trees include:

*Lower Eyre Peninsula* – Koppio Hills (L. Bebbington pers. comm.);

*Adelaide Hills* – Between Mylor and Aldgate and near Charleston (N. Mallen pers. comm.);

*Fleurieu* – Cox Scrub CP (between Mt. Compass and Ashbourne) spreading to distance of 100 m (R. Chapman pers. comm.); and

*Kangaroo Island* – Middle Reservoir (B. Overton pers. comm.).

Figure 5 shows reported locations of *E. globulus* in SA, categorised into indigenous (*E. globulus* spp. *bicostata*) and naturalised populations.

Within Australia. *E. globulus* is recorded as a weed in certain situations in Victoria, NSW and Tasmania (Lazarides et al. 1997). Localised patches of seedlings frequently occur adjacent to plantings in Victoria, in moderately to highly disturbed habitats such as roadsides (G. Carr pers. comm.).

Internationally. *E. globulus* is widespread in coastal areas of California, where it is considered one of the most invasive pest plants of native vegetation (CalEPCC 1999). In Europe, *E. globulus* has naturalised in France, Ireland, Spain, Italy and Portugal (Flora Europaea 2001). However, despite being introduced to Europe in the late 1800s, it has not spread vigorously enough to be considered a significant invader (Le Floc'h 1991).

### **Establishment**

*E. globulus* has relatively large seeds for the genus (1×2 mm, Bean and Russo 1986) and does not need light as a germination trigger, suggesting greater establishment ability amongst existing plants compared to other eucalypt species. However, despite being in cultivation for over a century in SA it does not have a history of establishing readily amongst existing vegetation in this State. In a recent unpublished study (P. Bulman and M. England pers. comm.), a few seedlings were found around mature *E. globulus* trees at only 3 out of 14 sites surveyed in the Mt Lofty Ranges, and seedlings tended to be where existing vegetation had been previously disturbed (e.g., by firebreak grading or on roadsides). However, seedlings from approximately 40 year old *E. globulus* have been observed establishing on the margins of open forest at Middle Reservoir on Kangaroo Island (B. Overton pers. comm.), and seedlings have been observed in native vegetation in the Koppio hills on the lower Eyre Peninsula (L. Bebbington pers. comm.).

In California, *E. globulus* has invaded coastal grasslands and shrublands, riparian areas and moist slopes (Randall and Marinelli 1996, CalEPPC 1999), but coastal fogs are important in their persistence (Bean and Russo 1986).

### **Reproduction**

Reproduction is similar to *E. cladocalyx*. Jordon et al. (1999), in crossing trials of *E. globulus* spp. *globulus*, found that time to first flowering varied from 2 to >5 years, with flowering mostly beginning by 4 years of age. Jordon et al. (1999) also noted from previous studies that fast-growing trees may not flower until they have been growing for 4 or more years and that canopy closure in plantations (after 4-5 years of growth) suppressed flowering. Thus the reproductive potential of short-rotation plantation *E. globulus* may be constrained in SA.

*E. globulus* does not reproduce vegetatively, but does regenerate from cut stumps by growth from epicormic buds.

### **Dispersal**

Dispersal ability is similar to that of *E. cladocalyx*. *E. globulus* seedlings observed on Kangaroo Island, SA were found 5-15 m from the edge of the tree canopy. Hardener et al. (1998) considered *E. globulus* ssp. *globulus* populations to have limited seed dispersal distance. Jacobs (1955 in Bean and Russo 1986) observed that *E. globulus* seed usually

fell within 100 feet of the parent tree, but considered that some flood, erosion and bird dispersal of seeds occurred.

## **IMPACTS**

### **Density**

Owing to the general lack of spread of *E. globulus*, despite being in cultivation for over a century, we consider that *E. globulus* may only reach a **low** density in native vegetation in southern SA if any spread from plantings is not controlled. It is limited in establishment ability and both juvenile and established trees have a high moisture requirement. *E. globulus* has also been observed to be susceptible to borers (J. Edwards pers. comm.) and crown rot (H. Longbottom pers. comm.).

The densest example of *E. globulus* observed was the site at Middle River Reservoir on Kangaroo Island. Here, trees planted approximately 40 years ago had produced seedlings of many age classes (up to 15 m in height) at a density of around 1-2 trees/m<sup>2</sup>, within 10-15 m of the parent trees' canopies. This is a high density, but the location on an internal formed driveway suggests tree seedlings may have had less competition during establishment than would occur in intact native vegetation.

### **Competitiveness**

At a low density *E. globulus* would have marginal effects on establishment, biomass and diversity of local native plant species. The trees are structurally similar to local SA eucalypts of high rainfall sites (e.g., *E. leucoxylon*) and thus understorey species would have similar growth conditions.

### **Movement**

At the predicted low density, with tall, straight stems and with a habit of shedding of lower branches, *E. globulus* will have negligible impacts on movement of fauna or people.

### **Health risks**

There are no reported health risks to animals or people associated with *E. globulus*.

### **Ecosystem health**

Large-scale *E. globulus* plantations are predicted to cause a lowering of groundwater levels in areas with shallow water tables (Dillon et al. 2001), but at a low density in native vegetation their effect would be negligible. There is no evidence to suggest that *E. globulus* will have a detrimental effect on ecosystem structure and functioning. It is likely that this species would function in the ecosystem in a similar way to the local native eucalypts.

## POTENTIAL DISTRIBUTION

### Climate tolerances

In California, *E. globulus* is mostly found in areas that have an annual rainfall of 600-1100 mm and not below 500 mm (Bean and Russo 1986). In 1910, Sellers wrote that “the blue gum groves upon the dry slopes and crests of the Coast Range hills owe their thrift principally to the prevalence of fogs, for ordinarily they will not succeed in dry localities”. California was excluded from the climate matching due to the key influence of summer fogs on *E. globulus* persistence, which cannot be taken account of in the CLIMATE model. Southern Europe was also excluded from the climate matching analysis as specific location information was not located.

A climate match for *E. globulus* ssp. *globulus* was done based on its native distribution in Tasmania and Victoria (AVH 2001), and the most extensive naturalised populations in SA (on Kangaroo Island and at Mt Gambier, State Herbarium records). This indicated that *E. globulus* ssp. *globulus* was climatically suited to wetter, southern regions of the agricultural zone of SA.

### Soil tolerances

In Tasmania, *E. globulus* grows in undulating country and in loamy soils in moist valleys (Chippendale 1988). In California it has naturalised especially on granite-derived soils. The best developed trees are found on “moderately fertile loams or heavy well drained soil” (Bean and Russo 1986). *E. globulus* does not occur naturally on poorly-drained soils or on strongly calcareous or alkaline soils (Bean and Russo 1986).

PIRSA Land Information soil attributes and classes selected for *E. globulus* were:

- Alkalinity - non-alkaline surface and subsoil;
- Inherent Fertility - moderate to very high fertility; and
- Susceptibility to Waterlogging - moderately to rapidly well-drained.

### Areas at risk

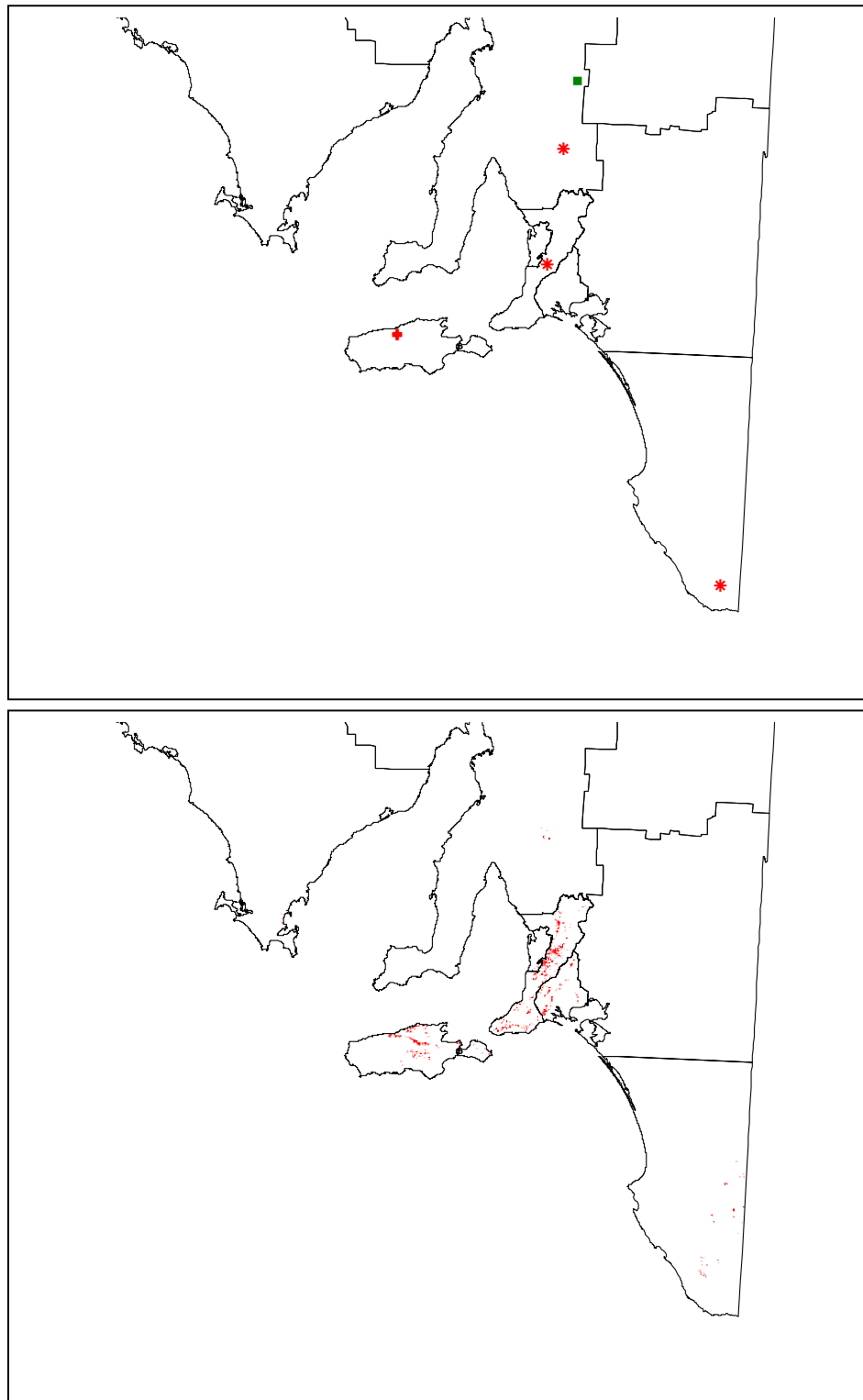
The areas and regional proportions of native vegetation in SA with potential for invasion by *E. globulus* ssp. *globulus* are shown in Figure 5 and Table 5 respectively.

**Table 5. Regional proportions of native vegetation with potential for invasion by *Eucalyptus globulus* spp. *globulus*.**

Region	Proportion of native vegetation at risk
Eyre	0%
Northern Agricultural Districts	0%
Mt Lofty Ranges / Adelaide Metropolitan	19%
Kangaroo Island	3%
Murray Darling Basin	0%
South-East	0%
<i>Southern SA (all of above regions)</i>	1%
Rangeland / Aboriginal Lands	0%

#### **Risk of hybridisation of *E. globulus* spp. *globulus* with local eucalypts**

During preparation of this report various people expressed concern about the risks of hybridisation of *E. globulus* with SA eucalypts, particularly due to the number of plantations (containing thousands of trees) being established. Recent research into this (P. Bulman and M. England pers. comm.) found no evidence of hybridisation between *E. globulus* and *E. viminalis*, *E. cosmophylla* or *E. ovata*, when examining seedlings grown from seed collected from 14 sites in the Mt Lofty Ranges. Ellis et al. (1991) investigated crosses between a range of *Eucalyptus* species and concluded that the likelihood of hybridisation decreases significantly with taxonomic distance. Within SA, *E. globulus* ssp. *globulus* is most closely related to the outlying *E. globulus* ssp. *bicostata* population at Burra. There may be a significant risk of intra-specific crossing at Burra if *E. globulus* ssp. *globulus* (Tasmanian bluegum) is planted in close proximity (i.e. within less than 1 km, see Potts et al 1988, Hardner et al. 1998) to the SA indigenous sub-species. Other southern SA eucalypts in the same taxonomic series as *E. globulus* (i.e., Viminalales) are *E. goniocalyx*, *E. viminalis* and *E. dalrympleana* (Nicolle 1997). However, each of these species also occurs within the natural range of *E. globulus* in Tasmania and/or Victoria. The natural co-habitation of these species suggests that, at natural densities, the risks and/or consequences of hybridisation are minor. Further comment on the risk of hybridisation with other SA eucalyptus species is beyond the scope of this report.



**Figure 5. Known locations of native and naturalised *Eucalyptus globulus* (top) and areas of native vegetation with potential for invasion by *E. globulus* spp. *globulus* in SA (bottom). Location symbols are: ■ State Herbarium of SA indigenous records, \* State Herbarium of SA naturalised records, + Authors naturalised records.**

## ***Eucalyptus grandis* W. Hill ex Maiden (Myrtaceae)**

### **Flooded gum**

#### **PLANT DESCRIPTION**

*Eucalyptus grandis* is a tall tree, growing 50-70 m in its native range (Hill 1991).

#### **HISTORY OF USE IN SA**

*E. grandis* has been in cultivation in SA since at least the 1970s (Mulvaney 1991). The species is currently used on a small-scale for farm forestry in high rainfall areas of SA. *E. grandis* has been shown to be slow growing in comparison to other eucalypts in trials at Mt Gambier (Cotterill et al. 1985).

#### **ORIGINS**

*E. grandis* is native to the coastal ranges of eastern NSW (north from Newcastle) and Queensland (Hill 1991, Chippendale 1988, AVH 2001). In its natural habitat it is a community dominant species found in "tall wet forest or rainforest margins on fertile alluvial soils along valley floors" (Hill 1991).

#### **INVASIVENESS**

##### **Naturalisation history**

Within SA. *E. grandis* has not been recorded as naturalised in SA, nor have any personal observations of seedlings/saplings adjacent to planted trees been reported for this project.

Within Australia. This species is not recorded as a weed by Lazarides et al. (1997).

Internationally. *E. grandis* is weedy in forest gaps, plantations and watercourses in sub-tropical (north-east) South Africa (Henderson 1995).

##### **Establishment**

The seed of *E. grandis* is much smaller than *E. globulus* or *E. cladocalyx*, indicating that it has fewer reserves for seedling establishment. Considerable disturbance to existing vegetation would need to occur (e.g., fire or soil cultivation) for *E. grandis* to establish.

##### **Reproduction**

The slow growth rate of *E. grandis* in SA would delay time to flowering well beyond 3 years of age. The species produces an average of 6700 seeds per 10 grams (ATSC 2001), but the slow release of seeds from capsules means that seed rain is likely to be less than 1000 seeds/m<sup>2</sup>/year. No vegetative reproduction occurs in this species.

## Dispersal

As with *E. globulus* and *E. cladocalyx*, seed from this species is likely to be shed only within approximately 30 m of parent trees.

## IMPACTS

### Density

*E. grandis* is unlikely to readily establish and persist in native vegetation in SA, due to a poor climate match (see potential distribution below) and poor establishment ability. Thus we consider that it may achieve a **very low** density in native vegetation in high rainfall areas of SA, if it does eventually spread from plantings.

### Competitiveness

At a very low density *E. grandis* would have negligible effects on establishment, biomass and diversity of local native plant species.

### Movement

At a very low density and with tall, straight stems, any naturalised *E. grandis* saplings or trees would not interfere with movement of people or animals.

### Health risks

There are no known health risks associated with *E. grandis*.

### Ecosystem health

No effect likely at a low density.

## POTENTIAL DISTRIBUTION

### Climate tolerances

In SA *E. grandis* needs at least 650 mm average annual rainfall for reasonable growth rates (Boomsma 1983). A climate match was done based on its native distribution in NSW and Queensland (AVH 2001). There were no matches to locations within SA. In its natural range *E. grandis* receives summer rainfall, and seedlings would have difficulty surviving the arid summers which occur in SA.

### Soil tolerances

*E. grandis* prefers deep, fertile, acid-neutral soils (Hill 1991, Boomsma 1983). No soil matching was done for SA as the climate was deemed unsuitable for naturalisation.

### Areas at risk

*E. grandis* does not present a significant risk of naturalisation in SA.



## ***Eucalyptus occidentalis* Endl. (Myrtaceae)**

### **Flat-topped yate, Swamp yate**

#### **PLANT DESCRIPTION**

*Eucalyptus occidentalis* is a medium tree which grows to 20m tall (Chippendale 1988).

#### **HISTORY OF USE IN SA**

*E. occidentalis* has been in cultivation in SA since the 1960s for use as farm trees and near saline areas. In the last decade the species has been used for managing dryland salinity. *E. occidentalis* is planted in soil water recharge areas, to help reduce flow to the soil water table in saline discharge areas (H. Lamont pers. comm.).

#### **ORIGINS**

*E. occidentalis* is native to south-west Western Australia where it usually grows on alluvial flats subject to flooding (Chippendale 1988).

#### **INVASIVENESS**

##### **Naturalisation history**

Within SA. *E. occidentalis* has not been officially recorded as naturalised in SA. Seedlings adjacent to plantings have rarely been observed. Occasional regeneration following death of planted trees has been observed on the Eyre Peninsula (J. Edwards pers. comm.), and some seedlings have been observed at the Kanmantoo mine site in the Adelaide Hills (J. Scarvelis pers. comm.).

Within Australia. *E. occidentalis* is not recorded as a weed by Lazarides et al. (1997). In Victoria there are at least 20 locations where *E. occidentalis* has become locally naturalised including the Wimmera and Ocean Grove near Geelong (G. Carr pers. comm.).

Internationally. *E. occidentalis* is used for saltland reclamation and forestry in the Mediterranean region (Le Houerou 1986, Saporito 1998). However, no information on the species' naturalisation status in this region has been located.

##### **Establishment**

In Western Australia, *E. occidentalis* occurs naturally in areas subject to inundation by floodwaters (i.e. swamps and flats adjacent to watercourses). *E. occidentalis* seedling recruitment occurs on the margins of such wetlands, where floating seeds collect in the flotsam bands (of vegetative material) which are formed as floodwaters recede (Froend and van der Moezel 1994). *E. occidentalis* requires light to stimulate seed germination

(Zohar et al 1975). Thus seedling establishment appears to be limited to bare soil surfaces (i.e. following flooding) that remain wet for a relatively long period.

### **Reproduction**

*E. occidentalis* will flower within three years of germination. Zohar (1975) observed flowering and fruiting to be quite common on nursery seedlings. *E. occidentalis* produces an average of 1500 viable seeds per 10 g (ATSC 2001), and has no vegetative reproduction. Seed rain is likely to be less than 1000 seeds/m<sup>2</sup>/year.

### **Dispersal**

The seed of *E. occidentalis* is not winged, and is likely to fall from capsules to within 30 m from the parent tree (Cremer 1977). Dispersal by water does occur for *E. occidentalis* (Froend and van der Moezel 1994).

## **IMPACTS**

### **Density**

There are very limited observations of volunteer seedlings of *E. occidentalis* in SA, none of which occurred in native vegetation. *E. occidentalis* is also limited in its establishment ability amongst other vegetation. Thus, we consider that it may achieve a **very low** density in terrestrial native vegetation in SA.

There is the possibility that *E. occidentalis* may achieve a greater density in wetland areas in SA. However, until *E. occidentalis* is found to produce seedlings in such areas, this remains speculation.

### **Competitiveness**

At a very low density *E. occidentalis* would have negligible effects on establishment, biomass and diversity of local native plant species.

### **Movement**

*E. occidentalis* would have a negligible effect on the animals and humans at its predicted low density.

### **Health risks**

There are no known health risks associated with *E. occidentalis*.

### **Ecosystem health**

No effect likely at a low density.

## POTENTIAL DISTRIBUTION

### Climate tolerances

A climate match was done based on the native distribution of *E. occidentalis* in Western Australia (AVH 2001).

### Soil tolerances

In Western Australia, *E. occidentalis* occurs on alluvial flats subject to flooding, wet depressions and clay flats (Gardner 1979). In Victoria, seedlings originating from plantings have been observed on soils of granitic, volcanic and alluvial origins as well as tertiary sandy loams (G. Carr pers. comm.).

PIRSA Land Information soil attributes and classes selected for *E. occidentalis* were:

- Depth to Water Table – 0-50cm or above surface for up to 10 months

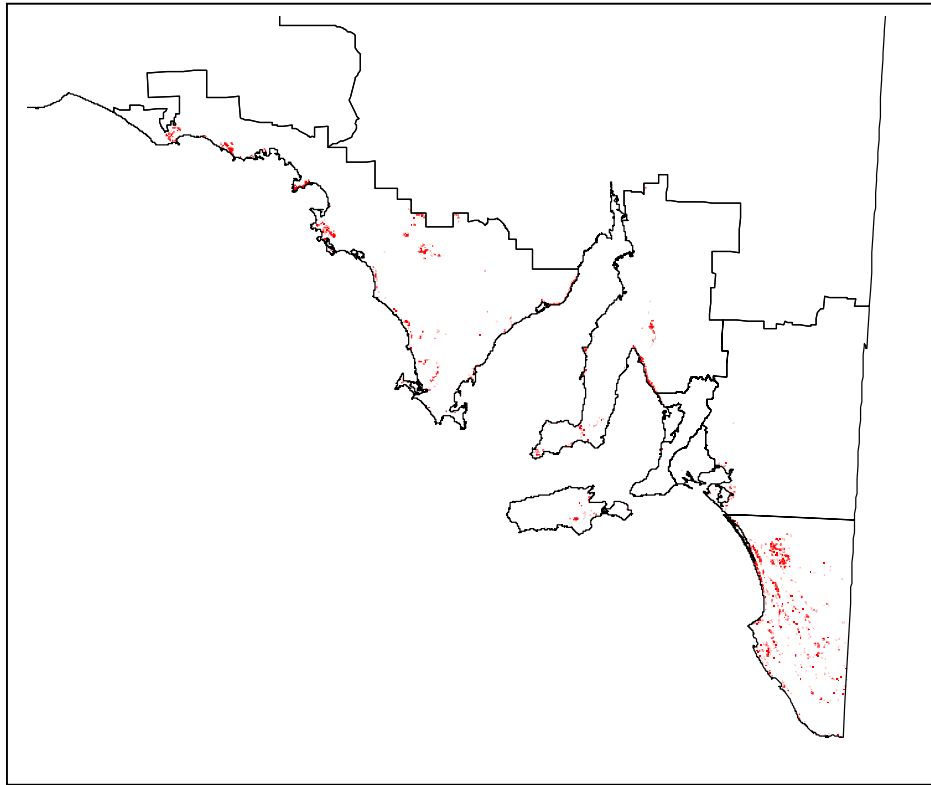
Note however that seedlings have been observed upslope in Victoria (G. Carr pers. comm.).

### Areas at risk

The areas and regional proportions of native vegetation in SA with potential for invasion by *E. occidentalis* are shown in Figure 6 and Table 6 respectively.

**Table 6. Regional proportions of native vegetation with potential for invasion by *Eucalyptus occidentalis*.**

Region	Proportion of native vegetation at risk
Eyre	3%
Northern Agricultural Districts	3%
Mt Lofty Ranges / Adelaide Metropolitan	2%
Kangaroo Island	1%
Murray Darling Basin	0%
South-East	17%
<i>Southern SA (all of above regions)</i>	3%
Rangeland / Aboriginal Lands	0%



**Figure 6.** Areas of native vegetation with potential for invasion by *Eucalyptus occidentalis* in SA. No locations of naturalised *E. occidentalis* were known.

## ***Eucalyptus platypus* Hook. (Myrtaceae)**

### **Round leaf moort**

#### **PLANT DESCRIPTION**

*Eucalyptus platypus* is a tree which grows to 9 m tall (Chippendale 1988).

#### **HISTORY OF USE IN SA**

*E. platypus* has been in cultivation in SA since 1912, but has been listed in seed catalogues more frequently since the 1970s (Mulvaney 1991). *E. cernua* (formerly *E. nutans*) has also been sold as *E. platypus* in the past (M. O'Leary pers. comm.). *E. platypus* has been commonly planted to create farm windbreaks. However, it has declined in popularity since gaining a reputation for blowing over in strong winds, particularly on sandy and shallow skeletal soils. Nonetheless, the species is tolerant of high soil pH (Bell et al. 1993), high soil salinity (Pepper et al. 1986) and drought (White et al. 2000). It is recommended in Western Australia for reclamation of sandplain seeps (Wright 1991), and trial plantings on sandy recharge areas have occurred in the last decade in SA.

#### **ORIGINS**

*E. platypus* is native to southern Western Australia, in coastal areas from Albany to Esperance, and inland to Gnowangerup (Chippendale 1988). Two varieties were known; var. *platypus* and var. *heterophylla*. Recent taxonomic revisions have changed *E. platypus* var. *heterophylla* to a new species, *E. utilis*. No distinction is made between the (former) varieties in the following discussion.

#### **INVASIVENESS**

##### **Naturalisation history**

Within SA. *E. platypus* has not been recorded as naturalised in SA. However, seedlings have been occasionally observed where planted trees have fallen over or been cut down, on lower Eyre Peninsula (J. Edwards pers. comm.), Yorke Peninsula (R. Storr pers. comm.), the Mid North (H. Longbottom pers. comm.) and Kangaroo Island (B. Overton pers. comm.).

Within Australia. *E. platypus* is not recorded as a weed by Lazarides et al. (1997). In Western Victoria there are at least 20 locations where *E. platypus* has become locally naturalised (G. Carr pers. comm.).

Internationally. No records have been found of *E. platypus* naturalising overseas.

## Establishment

The occurrence of seedlings when parent trees are blown over or cut down suggests that a combination of mass seed release from capsules (from drying branches), increased light availability and soil disturbance are important for seedling establishment in SA conditions. In addition, the understorey is sparse underneath *E. platypus*, so seedlings would face negligible competition during such establishment. Thus *E. platypus* appears to have a low establishment ability.

At the You Yangs Regional Park west of Melbourne, Victoria, thick stands of seedling *E. platypus* have occurred after a 1985 wildfire (G. Carr pers. comm.).

## Reproduction

Seed production of *E. platypus* has been measured at 220 viable seeds/g (var. *heterophylla*) to 390 seeds/g (var. *platypus*) (ATSC 2001). Seed rain is likely to be <1000 seeds/m<sup>2</sup>/year. Time to flowering is probably >3 years in SA, and the species does not reproduce vegetatively.

## Dispersal

As *E. platypus* is a relatively short tree, the distance of seed rain would probably be less than 15 m.

## IMPACTS

### Density

There are limited observations of volunteer seedlings of *E. platypus* in SA, none of which occurred in native vegetation. *E. platypus* is probably also limited in its establishment ability amongst other vegetation. Thus, if it does eventually spread from plantings, we consider that it may achieve a **very low** density in native vegetation in SA.

### Competitiveness

Planted *E. platypus* may compete considerably with adjacent vegetation, with a dense canopy and possible allelopathic effects. However, given that we assume it could only reach a very low density in native vegetation then competitive effects will be minimal.

### Movement

There would be negligible effects on movement through natural ecosystems from the presence of *E. platypus*, at the predicted very low density.

### Health risks

There are no known health risks associated with *E. platypus*.

### Ecosystem health

No effect likely at a low density.

## POTENTIAL DISTRIBUTION

### Climate tolerances

A climate match was done based on the native distribution of *E. platypus* in Western Australia (AVH 2001). This indicated that the majority of the southern agricultural zone was suitable for *E. platypus*.

### Soil tolerances

In Western Australia, *E. platypus* occurs in dense thickets on heavy, grey clay soils (Gardner 1979). *E. platypus* is also frequently associated with limestone (Gardner 1979). In Victoria, small naturalised populations occur on volcanic and alluvial soils high in clay content (G. Carr pers. comm.).

PIRSA Land Information soil attributes and classes selected for *E. platypus* were:

- Surface Texture – >60% of soil landscape unit is clay loam or clay
- Alkalinity – excluding non-alkaline surface and subsoil

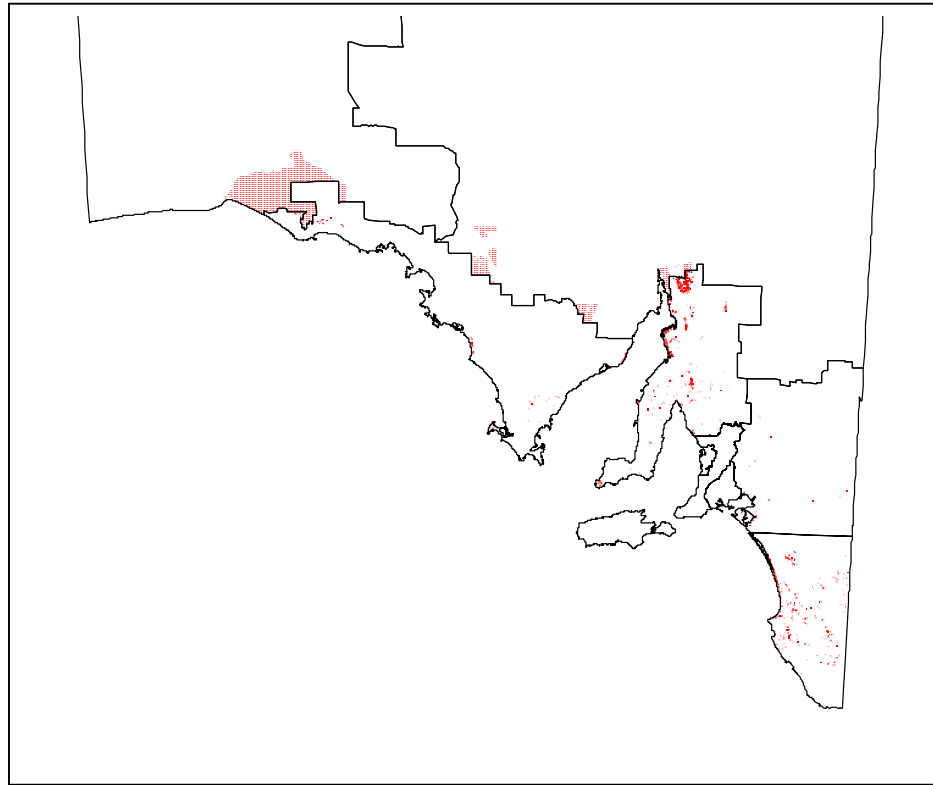
Calcareous earths and alkaline loam over clay soils (map units DD, Lb, Nb) were selected from the Atlas of Australian Soils (Northcote et al. 1968) for *E. platypus* in rangeland areas.

### Areas at risk

The areas and regional proportions of native vegetation in SA with potential for invasion by *E. platypus* are shown in Figure 7 and Table 7 respectively.

**Table 7. Regional proportions of native vegetation with potential for invasion by *Eucalyptus platypus*.**

Region	Proportion of native vegetation at risk
Eyre	1%
Northern Agricultural Districts	9%
Mt Lofty Ranges / Adelaide Metropolitan	0%
Kangaroo Island	0%
Murray Darling Basin	0%
South-East	7%
<i>Southern SA (all of above regions)</i>	3%
Rangeland / Aboriginal Lands	3%



**Figure 7.** Areas of native vegetation with potential for invasion by *Eucalyptus platypus* in SA. No locations of naturalised *E. platypus* were known.



## ***Eucalyptus saligna* Sm. (Myrtaceae)**

### **Sydney blue gum**

#### **PLANT DESCRIPTION**

*Eucalyptus saligna* is a tall tree which grows to 30-50 m in its native range (Costermans 1981).

#### **HISTORY OF USE IN SA**

*E. saligna* has been in cultivation in SA since the 1900s, but has been infrequently available in nursery catalogues over this time (Mulvaney 1991). Currently, small-scale use of this species occurs for farm forestry in high rainfall areas of SA. Moderate early growth rates were achieved in comparison to other eucalypts in trials at Mt Gambier, in the South-East of the state (Cotterill et al. 1985).

#### **ORIGINS**

*E. saligna* is native to the Great Dividing Range and adjacent coastal areas in eastern NSW (north from Bateman's Bay) and south-east Queensland (Costermans 1981, AVH 2001 and Chippendale 1988).

#### **INVASIVENESS**

##### **Naturalisation history**

Within SA. *E. saligna* has not been officially recorded as naturalised in SA. However, seedlings have been observed adjacent to planted trees in the Adelaide Hills at Mt Bold Reservoir (E. Robertson pers. comm.) and Bridgewater (C. Carter pers. comm.). Seedlings have not been observed amongst (slow growing) plantings in the Christies Beach, Lonsdale and Hackham areas (R. Taylor pers. comm.).

Within Australia. *E. saligna* is not recorded as a weed by Lazarides et al. (1997).

Internationally. *E. saligna* has been recorded as naturalised in South Africa (Wells et al. 1986).

##### **Establishment**

The establishment ability of *E. saligna* is similar to that of *E. grandis*.

##### **Reproduction**

The slow growth of *E. saligna* in SA would delay time to flowering well beyond 3 years of age. The species produces an average of 4800 seeds per 10 grams (ATSC 2001), but the

slow release of seeds from capsules means that seed rain is likely to be less than 1000 seeds/m<sup>2</sup>/year. *E. saligna* has no vegetative reproduction.

### **Dispersal**

As with *E. globulus* and *E. cladocalyx*, the seed from *E. saligna* is likely to be shed only within approximately 30 m of parent trees.

## **IMPACTS**

### **Density**

For similar reasons to *E. grandis* (i.e. poor climate match and establishment ability), we consider that *E. saligna* may achieve a **very low** density in native vegetation.

### **Competitiveness**

At a very low density *E. saligna* would have negligible effects on establishment, biomass and diversity of local native plant species.

### **Movement**

At a very low density and with tall, straight stems, any naturalised *E. saligna* would not significantly interfere with movement of people or animals.

### **Health risks**

There are no known health risks associated with *E. saligna*.

### **Ecosystem health**

No effect likely at a low density.

## **POTENTIAL DISTRIBUTION**

### **Climate tolerances**

A climate match was done based on the native distribution of *E. saligna* in NSW and Queensland (AVH 2001). There were no matches to locations within SA. In its natural range *E. saligna* receives summer rainfall, and seedlings would have difficulty surviving the arid summers that occur in SA.

### **Soil tolerances**

In its native range, *E. saligna* occurs on higher fertility, moist soils of lower slopes (Costermans 1981). No soil matching was done for SA as the climate was deemed unsuitable for naturalisation.

### **Areas at risk**

*E. saligna* does not present a significant risk of naturalisation in SA.

## ***Pinus brutia* Ten. (Pinaceae)**

### **Calabrian Pine, Turkish Pine, Brutian pine**

#### **PLANT DESCRIPTION**

*Pinus brutia* is a tree reaching a height of approximately 25 m (Hill 1998). This species is closely related to *P. halepensis* (Panetsos 1981) and natural hybrids occur (Panetsos et al. 1997).

#### **HISTORY OF USE IN SA**

Small-scale trial plantings (totalling several acres) of Cyprian *P. brutia* were established throughout SA from 1946 onwards (Bednall 1957). There has been renewed interest in the past decade for potential timber production in SA, in progeny trials run by ForestrySA and CSIRO (as part of a national genetic improvement program managed by the Australian Low Rainfall Tree Improvement Group). *P. brutia* is favoured over *P. halepensis* as it has straighter stems for timber production (P. Bulman pers. comm.). *P. brutia* has also been planted in townships as war memorial trees, seed being sourced from Gallipoli, Turkey.

#### **ORIGINS**

*P. brutia* is native to the eastern Mediterranean region and to western Asia, ranging from islands in the Aegean Sea (including Crete and Cyprus) to Turkey, Syria, Lebanon, Israel and western Iraq (Panetsos 1981).

#### **INVASIVENESS**

##### **Naturalisation history**

Within SA. *P. brutia* has been not been officially recorded as naturalised in SA. Seedlings have not been observed near *P. brutia* plantings in SA despite mature cones being present (W. Brown pers. comm., authors), although there are questions over the identity of seedlings arising from a mixed trial planting with *P. halepensis* south of Maitland on the Yorke Peninsula (H. Longbottom pers. comm.). However, the likelihood of naturalisation in SA would increase when *P. brutia* is planted in more locations, and when new genotypes are introduced.

Within Australia. *P. brutia* has been recorded as “weakly naturalised” adjacent to experimental forestry plantings in Western Australia in the last decade (Hill 1998, Hosking 2001).

Internationally. *P. brutia* has regenerated naturally in at least two countries to which it has been introduced (Rejmanek and Richardson 1996).

## Establishment

*P. brutia* seed is larger than that of *P. radiata* and *P. halepensis*, at 30-60 mg (Panetsos 1981). This may mean greater seed energy storage reserves for seedling establishment. Seed release occurs when mature cones open in late-spring and summer (Panetsos 1981). *P. brutia* is considered more drought tolerant than *P. halepensis* (Panetsos 1981 citing various references). In Crete, the species grows naturally in areas which have no rainfall from May to September (Cornet 1998). For *P. brutia* and *P. halepensis* from the Mediterranean region, seed germination requirements are similar and appear timed for autumn and early winter. However, seed of *P. brutia* from northern Greece (a region with a relatively cold and moist climate) needed chilling before it would germinate (Skordilis and Thanos 1995). *P. brutia* has been predicted to be an invasive pine species (Rejmanek and Richardson 1996), albeit marginally less so than *P. radiata* and *P. halepensis*.

Thus it is likely that *P. brutia* seedlings will establish at least as well as *P. halepensis* in native vegetation in SA.

## Reproduction

In progeny trials *P. brutia* tended to start flowering 1-2 years later than *P. halepensis* and also had significantly lower cone yields (Panetsos 1981). *P. brutia* does not reproduce vegetatively.

## Dispersal

Seed dispersal of *P. brutia* is likely to be similar to *P. halepensis*, with the majority of wind dispersed seeds landing in close proximity to parent trees. The slightly heavier seeds relative to their wing length (Richardson et al. 1990) may mean a shorter average dispersal distance for *P. brutia* in comparison to *P. halepensis*.

*P. brutia* is likely to provide a food source for black cockatoos (*Calyptorhynchus spp.*), in a similar manner to *P. radiata*, with subsequent risk of occasional long-distance dispersal.

## IMPACTS

### Density

With limited experience of *P. brutia* naturalisation in Australia, and scant information on its weed history overseas, we can only hypothesise as to its potential impacts in native vegetation in SA. Given its close relatedness to *P. halepensis*, its drought tolerance and the frequent occurrence of pure stands throughout its native range (Panetsos 1981) we suggest that its potential impacts would be similar to *P. halepensis* (see next section). Thus a **high** population density would eventually be achieved in native vegetation if the species were not controlled.

### Competitiveness, Movement, Health risks, Ecosystem health

As for *P. halepensis* (see next section).

## POTENTIAL DISTRIBUTION

### Climate tolerances

In its native range *P. brutia* commonly occurs in hilly areas receiving 500-1000 mm annual rainfall, but also grows on coastal plains receiving 250-375 mm annually (Hall et al. 1972). A climate match for *P. brutia* was done based on its native distribution in the Mediterranean (Panetsos 1981). This indicated that the upper Eyre, Mid North, Mt Lofty Ranges and Upper South-East were climatically suited to *P. brutia*.

### Soil tolerances

*P. brutia* grows on a similarly wide range of soil types to *P. halepensis*, including limestone substrates. However it is less tolerant of high levels of free carbonates than *P. halepensis*. (Panetsos 1981).

PIRSA Land Information soil attributes and classes selected for *P. brutia* were:

- Susceptibility to Waterlogging – moderately to rapidly well-drained.

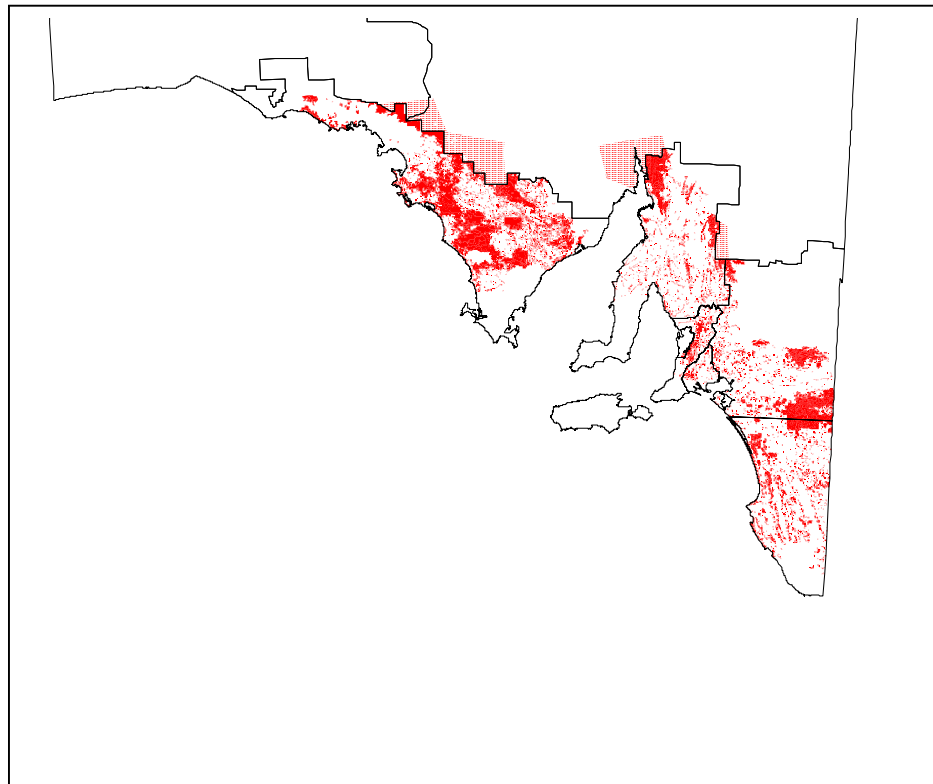
All map units of the Atlas of Australian Soils (Northcote et al. 1968) for *P. brutia* in rangeland areas were selected, excluding clay soils and lakes.

### Areas at risk

The areas and regional proportions of native vegetation in SA with potential for invasion by *P. brutia* are shown in Figure 8 and Table 8 respectively.

**Table 8. Regional proportions of native vegetation with potential for invasion by *Pinus brutia*.**

Region	Proportion of native vegetation at risk
Eyre	60%
Northern Agricultural Districts	38%
Mt Lofty Ranges / Adelaide Metropolitan	61%
Kangaroo Island	0%
Murray Darling Basin	31%
South-East	81%
<i>Southern SA (all of above regions)</i>	47%
Rangeland / Aboriginal Lands	1%



**Figure 8.** Areas of native vegetation with potential for invasion by *Pinus brutia* in SA. No locations of naturalised *P. brutia* were known.

## ***Pinus halepensis* Miller (Pinaceae)**

### **Aleppo pine**

#### **PLANT DESCRIPTION**

*Pinus halepensis* is a tree growing to 25-30 m tall (Hill 1998, Panetsos 1981).

#### **HISTORY OF USE IN SA**

*P. halepensis* has been in cultivation in SA since the mid 1800s (Mulvaney 1991) for windbreaks, timber, and as an ornamental. Forestry plantings commenced in 1876, with subsequent infrequent plantings at Bundaleer and Wirrabara (Northern Agricultural Districts), Wanilla (Eyre Peninsula) and Mt Burr (South-East) to 1957 totalling less than 100 acres (Bednell 1957). The species has been widely planted on farms and roadsides on the Eyre and Yorke Peninsulas.

#### **ORIGINS**

*P. halepensis* is native to the Mediterranean region and to western Asia. The species has a wide distribution within that area, "ranging from southern Europe and Morocco in the west, to Syria in the south-east and mainland Greece in the north-east of the Mediterranean Basin" (Panetsos et al. 1997).

#### **INVASIVENESS**

##### **Naturalisation history**

Within SA. *P. halepensis* is listed as naturalised in the Eyre Peninsula, Yorke Peninsula and Southern Lofty botanical regions of SA (Jessop 1993). There are also more recent herbarium records for the Murray region and Kangaroo Island. Naturalised plants are frequently observed adjacent to plantings. Regional observations and experiences with naturalised *P. halepensis* are as follows:

*Lower Eyre Peninsula* – The Southern Eyre Peninsula Aleppo Pine Management Group formed in 1997 to focus on the control of this species, as it has become widely naturalised in the region. The Group includes representatives from PIRSA, DEH, Local Councils, Private contractors, SA Water, Transport SA and Landcare groups. The Group has mapped approximately 250 infestations.

*Upper Eyre Peninsula* – *P. halepensis* have been widely planted in this region. There are now significant infestations, particularly in roadside native vegetation in the Lock and Elliston areas (B. Napier pers. comm.).

*Mid North* – *P. halepensis* was observed spreading from plantings in the Mallala, Balaclava, Halbury, Bundaleer, Jamestown and Wirrabara areas (authors, H. Longbottom, S. Meyer pers. obs.).

*Yorke Peninsula* - *P. halepensis* is a very bad weed problem across the Yorke Peninsula (H. Longbottom pers. comm.). The “Yorke Peninsula Feral Trees Management Group” (a subcommittee of Southern Yorke Peninsula Landcare Group Inc.) has formed to address the problem.

*Adelaide Hills* - In the foothills of the eastern Mt Lofty Ranges *P. halepensis* is present in good quality native vegetation having spread from only a few very old trees (B. Munday pers. comm.). There are infestations in the western Hills Face zone; e.g., Burnside, Brownhill Creek (authors & A. Crompton pers. obs.).

*Fleurieu* – Extensive thickets are present on Hindmarsh Island (authors & N. Mallen pers. obs.).

*Upper South-East* – Spreading into native vegetation on the Dukes Highway from plantings between Coonalpyn and Keith (authors).

Figure 8 shows reported locations of *P. halepensis* naturalised in SA.

Within Australia. *P. halepensis* is recorded as naturalised in south-west Western Australia, western Port Phillip Bay and the Ottways in Victoria and in New South Wales (AVH 2001, Lazarides et al. 1997).

Internationally. *P. halepensis* is a significant weed in New Zealand and South Africa (Richardson et al. 1994).

### **Establishment**

*P. halepensis* seed is relatively small for the genus, at 15-30 mg (Panetsos 1981), although at this weight it is a similar size to *P. radiata* seed. Seed is released from female cones in hot weather and also following fire (Nathan et al. 2000). Germination occurs rapidly, with no significant delay due to seed dormancy (Lepart and Debusche 1991).

*P. halepensis* appears to have a similar invasive ability to *P. radiata*. However, it has a much greater drought tolerance, being adapted to a semi-arid Mediterranean climate (Panetsos 1981). Thus *P. halepensis* can probably tolerate significant moisture stress, enabling the species to establish amongst existing vegetation. As with *P. radiata*, *P. halepensis* will establish in greater numbers in more open vegetation types and after disturbances such as clearing or fire. In Europe, dense herbaceous cover can strongly limit germination success (Lepart and Debusche 1991), and establishment and growth is poor where high rainfall and soil fertility promotes rapid growth of broadleaved, evergreen vegetation (Panetsos 1981). However, *P. halepensis* is adapted to germinate from autumn to winter (Skordilis and Thanos 1995), and on the less fertile soils found in SA this corresponds to when the herbaceous cover at ground level is relatively low.

*P. halepensis* is considered to be one of the most invasive of all pine species (Rejmanek and Richardson 1996). *P. halepensis* invades fynbos (heath) vegetation in the mediterranean climate area of south-west South Africa, but also wetter vegetation types in south-eastern South Africa (Richardson et al. 1994). In New Zealand it invades “extensively managed grasslands” on the South Island (Richardson et al. 1994). In SA, *P. halepensis* has been observed invading woodlands, mallee, grasslands and coastal dunes.



## Reproduction

In its native range, *P. halepensis* produces viable seed from around 12-15 years of age (Lepart and Debusche 1991). However, forestry progeny trials have observed flowering as early as 3 years of age (Panetsos 1981). Cone maturation and seed release occurs two years after pollination (Panetsos 1981). Annual seed production has been measured at 17400 seeds/tree/year. Annual seed fall estimates range from 25 seeds/m<sup>2</sup> at the edge of a mature forest (Lepart and Debusche 1991) to 240 seeds/m<sup>2</sup> under the tree canopy (Nathan et al. 1999). *P. halepensis* does not reproduce vegetatively.

## Dispersal

Black cockatoos have been observed feeding on *P. halepensis* cones on the lower Eyre Peninsula (P. Sheridan pers. comm.). Seed dispersal of *P. halepensis* is likely to be similar to that of *P. radiata*. Nathan et al. (1999) found that only 1.6-3.3% of *P. halepensis* seeds landed in the 20-110 m zone from parent trees.

## IMPACTS

### Density

**High** density infestations of *P. halepensis* have been observed on Hindmarsh Island, the Yorke Peninsula, and Eyre Peninsula. In the latter two areas the large visual weed impact of this species has meant that groups have been formed to combat the problem. In Europe, *P. halepensis* does not regenerate under its own canopy, due to competition from shade-tolerant shrubs and herbivory and/or predation of seedlings (Lepart and Debusche 1991, Nathan et al. 2000). The absence of these destructive factors in SA may explain the high seedling densities, and the subsequent dense thickets observed under parent trees.

### Competitiveness

*P. halepensis* has similar competitive effects to *P. radiata* in native vegetation (see next section). It forms a tall, dense thicket which excludes or significantly reduces the growth of shade-intolerant, native species. Needle litter may also inhibit regeneration of native plants. In the Mediterranean region, *P. halepensis* forms pure stands, excluding other tree species (Panetsos 1981).

In 'Gully Reserve', Burnside, *P. halepensis* removal has dramatically increased the growth of native sheoaks (*Allocasuarina* sp.), and allowed a vigorous native understorey of *Lomandra* sp., *Themeda triandra* and *Stackhousia* sp. to grow (A. Crompton pers. comm.).

### Movement

Effects on movement are similar to those for *P. radiata*. Dense thickets of various age classes significantly reduce movement through more naturally open vegetation types such as open woodlands, mallee and grasslands. In vegetation with an already dense understorey, there would be no effect on movement.

### Health risks

Pine species are not recorded as a significant animal or human health risk.

## **Ecosystem health**

Pine seeds provide an important alternative food source for black cockatoos, whose original food sources (e.g., *Allocasuarina* spp., *Banksia* spp. and *Hakea* spp.) have declined due to clearing of native vegetation. However, the simplification of the vegetation structure and the loss of native plant diversity as pines invade native vegetation will reduce their habitat value for other native wildlife. Thus a positive outcome for one species is cancelled out by a negative outcome for other species.

*P. halepensis* is highly fire adapted (Richardson et al. 1990), with a relatively short juvenile period for pines, many seeds held strongly in cones until post-fire tree death, leaves with a high oil content and accumulation of flammable leaf and stem litter. Whilst many native species are similarly fire-adapted, the greater rate of accumulation of biomass of *P. halepensis* is likely to significantly increase the intensity of fires.

Dense infestations of pines, having greater biomass than the original vegetation, may reduce rainfall infiltration to the soil water table or even directly reduce the water table depth (Dillon et al. 2001). This is beneficial in regions where overclearing has led to raised water tables and salinity concerns. However, this is a threat where groundwater is used for regional water supplies (e.g., lower Eyre Peninsula). In South Africa, the "Working For Water" program is spending millions of dollars on the removal of woody weeds such as pines and acacias from native vegetation, to restore stream flows to water storage dams (Working for Water 2001).

## **POTENTIAL DISTRIBUTION**

### **Climate tolerances**

A climate match for *P. halepensis* was done based on its naturalised distribution in Australia (AVH 2001 and authors pers. obs.) and South Africa (Henderson 1995) and its native distribution in the Mediterranean (Panetsos 1981). It indicated that the majority of southern SA was climatically suitable for *P. halepensis*.

### **Soil tolerances**

*P. halepensis* grows on a wide range of soil types from different parent material, including highly alkaline soils, shallow soils and moderately heavy clays. It does not tolerate poor drainage (Panetsos 1981).

PIRSA Land Information soil attributes and classes selected for *P. halepensis* were:

- Susceptibility to Waterlogging – moderately to rapidly well-drained.

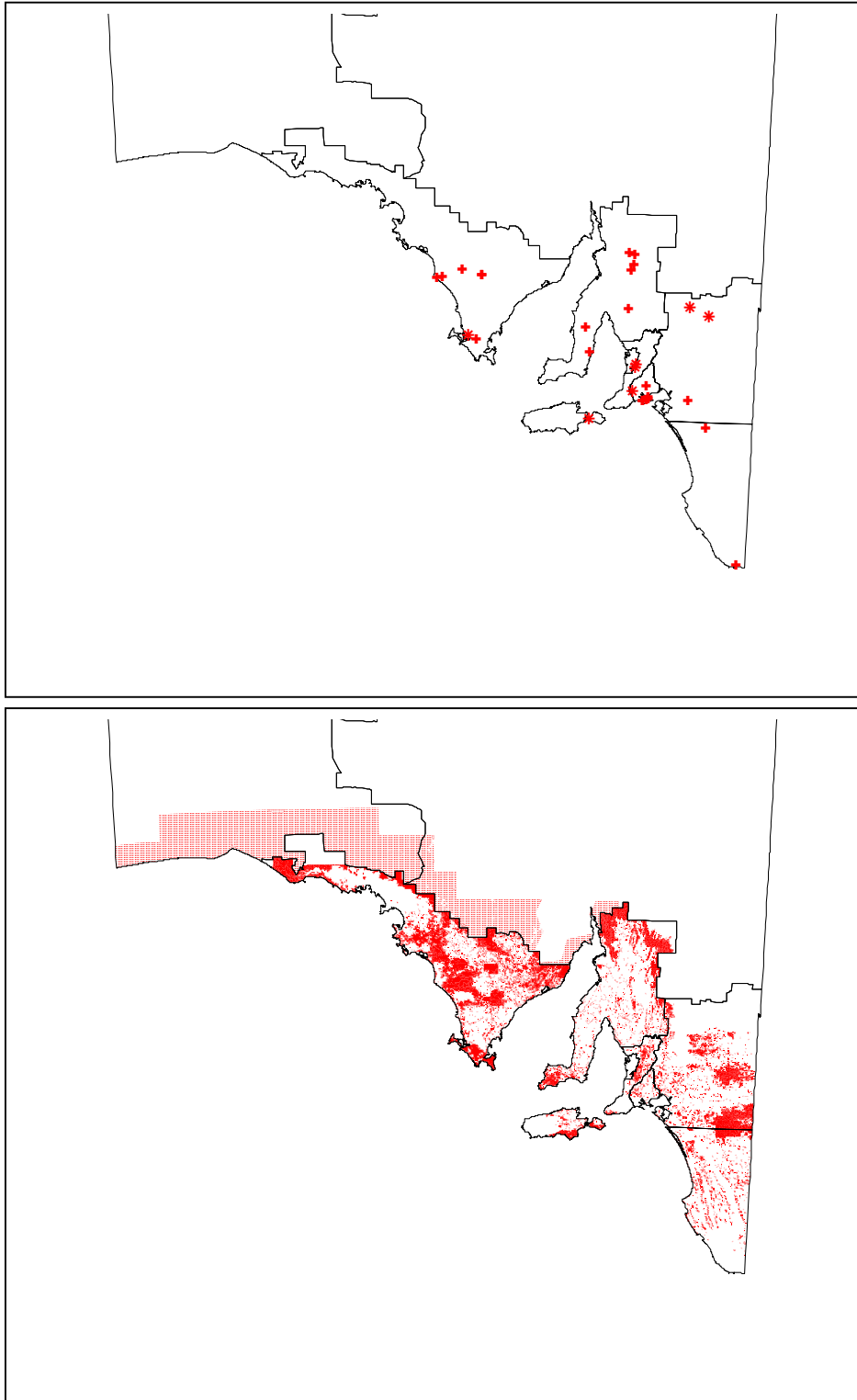
All map units of the Atlas of Australian Soils (Northcote et al. 1968) for *P. halepensis* in rangeland areas were selected, excluding clay soils and lakes.

### **Areas at risk**

The areas and regional proportions of native vegetation in SA with potential for invasion by *P. halepensis* are shown in Figure 9 and Table 9 respectively.

**Table 9. Regional proportions of native vegetation with potential for invasion by *Pinus halepensis*.**

Region	Proportion of native vegetation at risk
Eyre	84%
Northern Agricultural Districts	71%
Mt Lofty Ranges / Adelaide Metropolitan	66%
Kangaroo Island	29%
Murray Darling Basin	41%
South-East	59%
<i>Southern SA (all of above regions)</i>	65%
Rangeland / Aboriginal Lands	7%



**Figure 9.** Known locations of naturalised *Pinus halepensis* (top) and areas of native vegetation with potential for invasion by the species in SA (bottom). Location symbols are: \* State Herbarium of SA records, + Authors records.

## ***Pinus radiata* D.Don (Pinaceae)**

### **Radiata pine**

#### **PLANT DESCRIPTION**

*Pinus radiata* is a tree which grows to 35 m tall (Hill 1998).

#### **HISTORY OF USE IN SA**

*P. radiata* has been in cultivation in SA since 1862 (Mulvaney 1991), for timber, shelter-belts and as an ornamental. *P. radiata* plantations have been planted in the south-east of SA, in the Mt Lofty Ranges and the mid north of the state since the late 1800s (ForestrySA Info Sheet No. 4). Today over 100 000 hectares of this species are planted in the state, the majority of which is in the South-East region (ForestrySA 1999).

#### **ORIGINS**

*P. radiata* has a surprisingly small native distribution, restricted to the central coast of California. The species has undergone considerable breeding and selection for timber production.

#### **INVASIVENESS**

##### **Naturalisation history**

Within SA. *P. radiata* is listed as naturalised in the Northern Lofty, Southern Lofty and South-East botanical regions of SA (Jessop 1993). There are also more recent herbarium records for Kangaroo Island. Naturalised plants are frequently observed adjacent to plantations and windbreaks, especially on roadsides and in native vegetation. Conservation areas invaded by *P. radiata* include Belair NP, Deep Creek CP, Newland Head CP (R. Taylor pers. comm.), Eudunda Cemetery Reserve (A. Crompton pers. comm.) and many native forest reserves abutting plantations in the Mt Lofty Ranges and the South-East of the state.

In the South-East region, ForestrySA has been spending in the order of \$60,000 per year cleaning up large areas of *P. radiata* seedlings in their Native Forest Reserves. The seedlings were sourced from adjacent plantations, and dense thickets arose as a result of the 1983 Ash Wednesday wildfires (T. Wynnaiat pers. comm.). Volunteer groups such as bushcare and friends groups are actively involved in pine removal in the Mt Lofty Ranges, Fleurieu and Kangaroo Island regions.

*P. radiata* has also been observed to spread on the lower Eyre Peninsula (L. Bebbington, P. Sheridan pers. comm.). However, in places such as the Uley Basin, west of Port Lincoln, their growth is quite poor and probably limited by rainfall (J. Edwards pers. comm.).

Figure 10 shows reported locations of *P. radiata* naturalised in SA.

Within Australia. *P. radiata* is recorded as a weed for all Australian states (Lazarides et al. 1997). *P. radiata* is highly invasive in south-east Australia in areas receiving >600 mm average annual rainfall (Muyt 2001). The species is a frequent bushland invader adjacent to plantations in Victoria, New South Wales and the Australian Capital Territory.

Internationally. There are approximately 3 million hectares of *P. radiata* plantations worldwide and spread from plantations has been observed in New Zealand, South Africa, Chile and the Mediterranean region (Richardson et al. 1994, Flora Europaea 2001). *P. radiata* has invaded large areas in South Africa and New Zealand and is considered a major weed of natural areas (Richardson et al. 1994).

## **Establishment**

*P. radiata* seed is relatively small for the genus, at 15-42 mg (van der Sommen 1978). However, the seed is similar in size to those of Acacias and much larger than eucalypt seeds.

*P. radiata* has invaded forests, woodlands, heathlands and grasslands in Australia, New Zealand and South Africa (Richardson et al. 1994, Swarbrick 1984). Major disturbance to native vegetation by such means as grazing, clearing or fire will significantly increase the likelihood and rate of invasion by pines, but invasions do occur into relatively intact vegetation. In SA, van der Sommen (1978) observed colonisation into both disturbed and undisturbed eucalypt forest communities, at similar rates over a range of habitats and community types. Open vegetation types are more susceptible to invasion than are dense vegetation types such as blackberry or tall bracken thickets. However, as the number of seeds available increases there is an increased likelihood of invasion into any vegetation type (Richardson et al. 1994).

In SA, *P. radiata* has been observed establishing in eucalypt forest in the South-East, Mt Lofty Ranges and Kangaroo Island. Seedlings can establish amongst ground flora, and with some shading from native shrub and tree canopies. When shaded, seedlings have strong vertical growth to seek additional light. Secondary establishment of *P. radiata* seedlings has been observed under the canopy of parent trees.

Fire is a severe disturbance that dramatically enhances pine establishment. Cones on burnt branches open to cause a mass release of seeds, which readily establish on the fertile ash bed. After the 1983 Ash Wednesday wildfires in south-east SA, *P. radiata* seedling numbers were initially in the order of 1 million/ha, but self-thinned to around 10000/ha (T. Wynniat pers. comm.).

## **Reproduction**

In plantations *P. radiata* sets seed from around 10 years of age (Lewis et al. 1993). Burdon and Chilvers (1977) found seed-bearing cones on trees 12 years and older amongst eucalypt forest in the Australian Capital Territory. Minko and Aeberli (1986) estimated the minimum age of cone-bearing *P. radiata* was 21 years in tall, open eucalypt forest in north-east Victoria. Such trees had not borne cones until growing taller than the eucalypt canopy. In contrast, in the relatively-short fynbos vegetation in South Africa, Richardson et al. (1990) gave the minimum juvenile period as 5 years.

The canopy-held seedbank of *P. radiata* in plantations in SA has been estimated to peak at 3.6 - 8.3 million seeds/ha (van der Sommen 1978 sourcing unpublished data), which equates to less than 1000 seeds/m<sup>2</sup>. Annual seed release in 40 year old *P. radiata* at

Penola was in the order of 1-3 seeds/m<sup>2</sup> (van der Sommen 1978, sourcing unpublished data by R. Boardman). *P. radiata* does not reproduce vegetatively.

## Dispersal

Seed of *P. radiata* can occasionally be dispersed relatively long-distances by wind. Seed is relatively small, winged and is released from a tall canopy. Minko and Aeberli (1986) measured maximum dispersal distances ranging from 360 m to 1.53 km in north-eastern Victoria where there was no barrier to strong winds. However, the pine seeds most frequently land within 100 m from parent trees (Richardson et al. 1994). Minko and Aeberli (1986) observed exponential declines in seedling numbers with increasing distance from the edge of pine plantations. Van der Sommen (1978) quoted figures of 70% seed shed beneath the *P. radiata* canopy, 16-26% shed within 20 m from the canopy, and 4-7% within 20-100 m of the canopy.

Seed of *P. radiata* is also dispersed long-distances in SA by black cockatoos removing and feeding on cones (Attiwill 1970). This would be a small proportion of total seed dispersed by trees.

## IMPACTS

### Density

In high rainfall regions of SA *P. radiata* is frequently considered a serious weed by managers of native vegetation. The species is relatively slow to spread and relatively easy to control. However, if left uncontrolled it will eventually achieve a **high** density in native vegetation, particularly as older trees become the dominant canopy species and give rise to new seedlings. Approximately 100 seedlings per hectare have been observed in an area of Nangwarry Scrub in the South-east, which had not been burnt for several decades (T. Wynniat pers. comm.). Similar numbers were observed at Martyns Siding Reserve, west of Mt Gambier. After fire a very high density can be achieved, but the discussion below considers pine behaviour in the absence of fire.

### Competitiveness

Uncontrolled *P. radiata* has the potential to eventually form dense thickets and become the dominant canopy in areas of native vegetation in higher rainfall areas of SA. Subsequent dense shading and competition for moisture and nutrients will have major effects on the vigour, survival and regeneration of native plants. In addition, the formation of a thick layer of pine needles on the soil surface will inhibit seedling establishment by native plants. At Martyn's Siding in the South-East a reduction of greater than 50% in native species number and estimated biomass, was visually apparent after >3 decades of *P. radiata* invasion. In the ACT, Burdon and Chilvers (1994) observed a continuing decline in juvenile and adult eucalypt numbers whilst pine numbers continued to increase. In South Africa, *P. radiata* invasion has converted shrubland (fynbos) to pine forests, resulting in the local extinction of many native plants (Richardson et al. 1994).

### Movement

In forests and heath vegetation, *P. radiata* is unlikely to significantly limit movement of people or animals in comparison to such limits posed by the original vegetation. Even

after fire, the high density of *P. radiata* seedlings would not place significantly greater limits on movement in comparison to regenerating native trees and shrubs. However, *P. radiata* thickets replacing natural woodlands and grasslands will impede movement through increased density, height and biomass of trees in the vegetation.

### **Health risks**

Pine species are not known to pose a significant health risk to animals or humans.

### **Ecosystem health**

There is a similar conflict of interest for native fauna as exists with *P. halepensis*. *P. radiata* provides a food source for black cockatoos but the loss of native vegetation threatens the various habitats of other native fauna.

Fire risk is also likely to be similar to *P. halepensis*.

## **POTENTIAL DISTRIBUTION**

### **Climate tolerances**

A climate match for *P. radiata* was done based on its naturalised distribution in Australia (AVH 2001 and authors pers. obs.) and South Africa (Henderson 1995). This indicated that the South-East, southern Mt Lofty Ranges and Kangaroo Island are climatically suitable for naturalisation of *P. radiata*.

### **Soil tolerances**

*P. radiata* can grow on a wide range of soil types, but grows better on lighter-textured soils than heavier-textured soils. It does not tolerate waterlogging for long periods, and will grow on low fertility soils. (Lewis et al. 1993).

PIRSA Land Information soil attributes and classes selected for *P. radiata* were:

- Susceptibility to Waterlogging - moderately to rapidly well-drained.

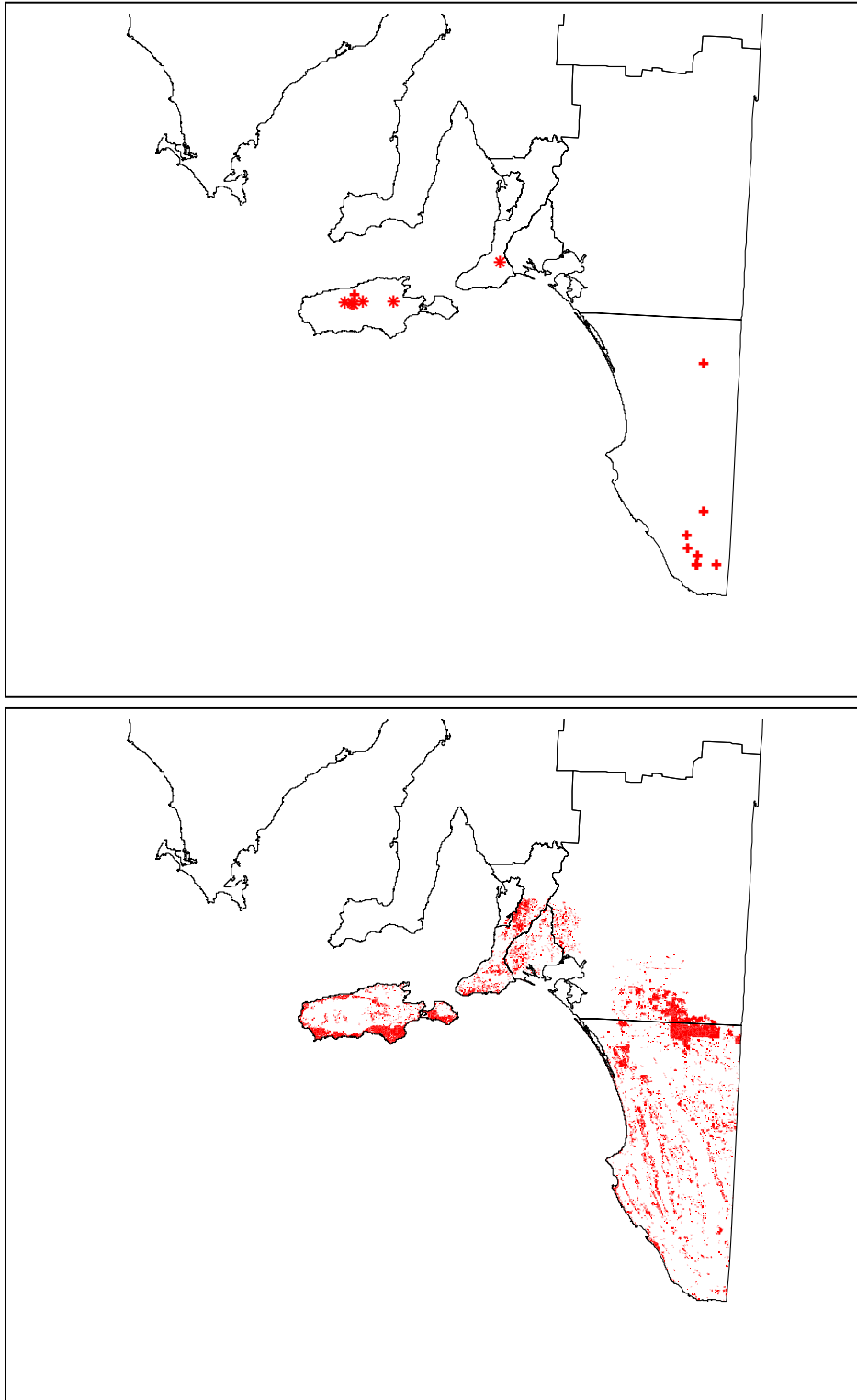
### **Areas at risk**

The areas and regional proportions of native vegetation in SA with potential for invasion by *P. radiata* are shown in Figure 10 and Table 10 respectively.



**Table 10. Regional proportions of native vegetation with potential for invasion by *Pinus radiata*.**

Region	Proportion of native vegetation at risk
Eyre	0%
Northern Agricultural Districts	0%
Mt Lofty Ranges / Adelaide Metropolitan	57%
Kangaroo Island	42%
Murray Darling Basin	6%
South-East	59%
<i>Southern SA (all of above regions)</i>	9%
Rangeland / Aboriginal Lands	0%



**Figure 10. Known locations of naturalised *Pinus radiata* (top) and areas of native vegetation with potential for invasion by the species in SA (bottom). Location symbols are: \* State Herbarium of SA records, + Authors records.**

## **Weed Risk Assessment Scoring for Trees**

Figures 11 and 12 show the weed risk assessment scoring for the tree species across southern SA (all regions excluding Rangelands / Aboriginal Lands). Key criteria scores are summarised in Table 11. Table 12 lists regional Weed Importance scores.

In general terms across southern SA, *Pinus halepensis* and *P. brutia* scored as very high environmental weed risks (weed importance score 209+), with *P. radiata* scoring as a medium weed risk (weed importance score between 29 and 84) due to a higher moisture requirement. *P. halepensis* and *P. brutia* posed the same category of environmental weed risk as feral olives, which are proclaimed in SA. *Casuarina glauca* and *Eucalyptus cladocalyx* scored as low environmental weed risks across southern SA (weed importance score between 3 and 29), whilst the remaining *Eucalyptus* spp. scored as a negligible weed risk (weed importance score <3) at this geographic scale.

The *Pinus* spp. scored as very high to high weed risks for the regions to which they were highly climatically suited, with high Impacts and Invasiveness scores.

*Casuarina glauca* scored as a low to medium weed risk in the regions of southern SA. Whilst it had similarly high invasiveness and impacts scores to the pines, its potential distribution was much more restricted.

The *Eucalyptus* spp. mostly presented a negligible weed risk in all regions. *E. globulus* spp. *globulus* was a low weed risk in the MLR/Metro region due to a higher potential distribution score than in other regions. *E. cladocalyx* scored as a medium weed risk in the MLR/Metro and SE regions, largely due to a higher potential distribution score and greater likely density than the other *Eucalyptus* spp. considered.

WEEDS:	Casuarina glauca	Eucalyptus cladocalyx	Eucalyptus globulus spp. globulus Tasmanian Bluegum	Eucalyptus grandis	Eucalyptus occidentalis	Eucalyptus platypus	Eucalyptus saligna	Pinus brutia	Pinus halepensis	Pinus radiata
	Swamp Oak	Sugar Gum		Flooded Gum	Flakopped Yate	Round leaf Mort	Sydney Bluegum	Turkish Pine	Aleppo Pine	Radiata Pine
<b>REGION:</b> Southern agricultural zone (NHT regions: Eyre, Northern Agricultural Districts, Mount Lofty Ranges, Metropolitan, Kangaroo Island, Murray-Darling Basin, South-East)										
<b>LANDUSE:</b> Native Vegetation										
Assumptions/Comments: On average across the state, there is no routine weed management. No stock grazing. No products leaving the landuse. Domestic animals are dogs and horseriding occasionally.										
<b>A) INVASIVENESS</b> Answer all questions with the landuse in mind, except for question 5(a)										
1. What is the weed's ability to establish amongst existing plants? 3 = very high 2 = high 1 = medium 0 = low ? = don't know	3	1	1	0	0	0	0	3	3	3
2. What is the weed's tolerance to average weed management practices in the landuse? These practices (or lack thereof) can be listed in the above landuse assumptions. 3 = very high 2 = high 1 = medium 0 = low ? = don't know	3	3	3	3	3	3	3	3	3	3
3. What is the reproductive ability of the weed:										
(a) Time to seeding? 2 = 1 year 1 = 2-3 years 0 = >3 years / never ? = don't know	0	0	0	0	1	0	0	0	0	0
(b) Seed set? 2 = high 1 = low 0 = none ? = don't know	1	1	1	1	1	1	1	1	1	1
(c) Vegetative spread? 2 = fast 1 = slow 0 = none ? = don't know	1	0	0	0	0	0	0	0	0	0
<b>TOTAL:</b> <b>SCORE FOR 3:</b> 3 = total of 5 or 6 2 = total of 3 or 4 1 = total of 1 or 2 0 = total of 0	2	1	1	1	2	1	1	1	1	1
4. How likely is long-distance dispersal by natural means:										
(a) Flying birds? 2 = common 1 = occasional 0 = unlikely ? = don't know	0	0	0	0	0	0	0	1	1	1
(b) Other wild animals?	0	0	0	0	0	0	0	0	0	0
(c) Water?	1	0	0	0	0	0	0	0	0	0
(d) Wind?	0	0	0	0	0	0	0	1	1	1
<b>TOTAL:</b> <b>SCORE FOR 4:</b> 3 = total of 6 to 8 2 = total of 3 to 5 1 = total of 1 or 2 0 = total of 0	1	0	0	0	0	0	0	2	2	2
5. How likely is long-distance dispersal by human means:										
(a) Deliberate by people? (ignore landuse) 2 = common 1 = occasional 0 = unlikely ? = don't know	2	2	2	1	2	2	1	1	2	2
(b) Accidentally by people?	0	0	0	0	0	0	0	0	0	0
(c) Contaminated produce?	0	0	0	0	0	0	0	0	0	0
(d) Domestic/farm animals?	0	0	0	0	0	0	0	0	0	0
<b>TOTAL:</b> <b>SCORE FOR 5:</b> 3 = total of 6 to 8 2 = total of 3 to 5 1 = total of 1 or 2 0 = total of 0	2	2	2	1	2	2	1	1	2	2
<b>TOTAL INVASIVENESS SCORE:</b>	9	6	6	5	5	5	5	9	9	9

Figure 11. Invasiveness scoring for the tree species using the Weed Importance Scoresheet.

WEEDS:		Casuarina glauca	Eucalyptus cladocalyx	Eucalyptus globulus spp. globulus	Eucalyptus grandis	Eucalyptus occidentalis	Eucalyptus platyphloia	Eucalyptus saligna	Pinus brutia	Pinus halepensis	Pinus radiata	
		Swamp Oak	Sugar Gum	Tasmanian Bluegum	Flooded Gum	Flak-topped Yate	Round leaf Mott	Sydney Bluegum	Turkish Pine	Aleppo Pine	Radiata Pine	
<b>B) IMPACTS</b>		Assume the average weed management practices have not changed to specifically target the weed, and it has spread across/along a whole paddock, orchard, plantation, nature reserve or water body. If the weed is well-controlled by these average practices then it will occur at a low density and will have minimal impacts.										
<b>What density would the weed achieve?</b>		L = LOW M = MEDIUM H = HIGH										
		H	M	L	L	L	L	L	H	H	H	
1. Does the weed reduce the establishment of desired plants?	3 = > 90% reduction 2 = 10-90% reduction 1 = < 10% reduction 0 = none ? = don't know	3	1	1	0	0	1	0	3	3	3	
2. Does the weed reduce the mature yield or amount of desired vegetation?	4 = > 90% reduction 3 = 25-90% reduction 2 = 10-25% reduction 1 = < 10% reduction 0 = none ? = don't know	4	2	1	0	0	0	0	4	4	4	
3. Does the weed reduce the quality of products or services obtained from the landuse?	3 = high 2 = medium 1 = low 0 = none ? = don't know	3	1	0	0	0	0	0	3	3	3	
4. Does the weed restrict the physical movement of people, animals, vehicles and/or water?	3 = high 2 = medium 1 = low 0 = none ? = don't know	2	0	0	0	0	0	0	2	2	2	
5. Does the weed affect the health of animals and/or people?	3 = high 2 = medium 1 = low 0 = none ? = don't know	0	0	0	0	0	0	0	0	0	0	
6. Does the weed have major, positive or negative effects on environmental health:												
(a) food/shelter?		1	0	0	0	0	0	0	0	0	0	
(b) fire regime?	-1 = major positive effect	0	0	0	0	0	0	0	1	1	1	
(c) increase nutrient levels?	1 = major negative effect	?	0	0	0	0	0	0	0	0	0	
(d) soil salinity?	0 = minor or no effect	0	0	0	0	0	0	0	0	0	0	
(e) soil stability?	? = don't know	0	0	0	0	0	0	0	0	0	0	
(f) soil water table?		1	0	0	0	0	0	0	1	1	?	
<b>TOTAL:</b>		<b>2</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>2</b>	<b>2</b>	<b>1</b>	
<b>SCORE FOR 6:</b>	3 = total of 4 to 6 2 = total of 2 or 3 1 = total of 1 0 = total of 0 or less	<b>2</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>2</b>	<b>2</b>	<b>1</b>	
<b>TOTAL IMPACTS SCORE:</b>		<b>14</b>	<b>4</b>	<b>2</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>0</b>	<b>14</b>	<b>14</b>	<b>13</b>	
<b>C) POTENTIAL DISTRIBUTION</b>		In the Board, what area of the landuse is suitable for the weed? 10 = 95-100% of landuse, 9 = 85-95%, 8 = 75-85%, 7 = 65-75%, 6 = 55-65%, 5 = 45-55%, 4 = 35-45%, 3 = 25-35%, 2 = 15-25%, 1 = 7.5-15%, 0.5 = 1-7.5%, 0 = <1%, ? = don't know										
		0.5	1	0.5	0	0.5	0.5	0	5	7	1	
<b>WEED IMPORTANCE SCORE</b>		Scores adjusted to range between 0 and 10										
<b>ADJUSTED INVASIVENESS SCORE:</b>		6.0	4.0	4.0	3.3	3.3	3.3	3.3	6.0	6.0	6.0	
<b>ADJUSTED IMPACTS SCORE:</b>		7.4	2.1	1.1	0.0	0.0	0.5	0.0	7.4	7.4	6.8	
<b>POTENTIAL DISTRIBUTION SCORE:</b>		0.5	1.0	0.5	0.0	0.5	0.5	0.0	5.0	7.0	1.0	
<b>WEED IMPORTANCE =</b>	(Multiplying the scores)	<b>22</b>	<b>8</b>	<b>2</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>0</b>	<b>221</b>	<b>309</b>	<b>41</b>	
<b>Number of questions answered as "don't know"</b>		<b>1</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>1</b>	

Figure 12. Impacts, Potential Distribution (for southern SA) and Weed Importance scoring for the tree species using the Weed Importance Scoresheet.

**Table 11. Summary of criterion and final scores for the tree species for southern SA within the native vegetation landuse. Scoring for wild olives has been included for comparison (APCC data).**

<b>Species</b>	<b>Invasiveness</b>	<b>Impacts</b>	<b>Potential Distribution</b>	<b>Weed Importance</b>
<i>Casuarina glauca</i>	6.0	7.4	0.5	22
<i>Eucalyptus cladocalyx</i>	4.0	2.1	1	8
<i>Eucalyptus globulus</i> ssp. <i>globulus</i>	4.0	1.1	0.5	2
<i>Eucalyptus grandis</i>	3.3	0.0	0	0
<i>Eucalyptus occidentalis</i>	3.3	0.0	0.5	0
<i>Eucalyptus platypus</i>	3.3	0.5	0.5	1
<i>Eucalyptus saligna</i>	3.3	0.0	0	0
<i>Pinus brutia</i>	6.0	7.4	5	221
<i>Pinus halepensis</i>	6.0	7.4	7	309
<i>Pinus radiata</i>	6.0	6.8	1	41
<b>Proclaimed:</b>				
<i>Olea europaea</i> (Feral olive)	6.7	6.8	5	228

**Table 12. Weed Importance scores for the tree species for different regions.**

Species	Eyre	NAD	MLR/ Metro	KI	MDB	SE	Range /AL
<i>Casuarina glauca</i>	22	44	22	22	22	44	0
<i>Eucalyptus cladocalyx</i>	0	0	76	0	17	42	0
<i>Eucalyptus globulus</i> ssp. <i>globulus</i>	0	0	9	2	0	0	0
<i>Eucalyptus grandis</i>	0	0	0	0	0	0	0
<i>Eucalyptus occidentalis</i>	0	0	0	0	0	0	0
<i>Eucalyptus platypus</i>	0	2	0	0	0	1	1
<i>Eucalyptus saligna</i>	0	0	0	0	0	0	0
<i>Pinus brutia</i>	266	178	266	0	133	355	22
<i>Pinus halepensis</i>	355	311	311	133	178	266	22
<i>Pinus radiata</i>	0	0	245	163	20	245	0

1. Regions are Eyre, Northern Agricultural Districts, Mt Lofty Ranges / Adelaide Metropolitan, Kangaroo Island, Murray Darling Basin, South-East and Rangeland / Aboriginal Lands.

## RESULTS: SHRUBS

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Photo 5. *Acacia cyclops* thicket on Yorke Peninsula. (Photo R. Melland)



Photo 6. *Acacia cyclops* under a roadside perch tree, near Milang, Fleurieu Peninsula. (Photo J. Virtue)



Photo 7. *Acacia saligna* seedlings in mallee heath vegetation near Keith, upper South-East. (Photo J. Virtue)



Photo 8. *Acacia saligna* seedling establishing in dense groundcover near Keith. (Photo J. Virtue)



Photo 9. *Chamaecytisus palmensis* seedlings in roadside vegetation on Kangaroo Island. (Photo R. Melland)



## ***Acacia cyclops* A.Cunn ex G. Don (Fabaceae)**

### **Western coastal wattle**

#### **PLANT DESCRIPTION**

*Acacia cyclops* is a dense, rounded woody shrub to small tree, 1-6 m tall (Whibley and Symon 1992, Cowan and Maslin 2001).

#### **HISTORY OF USE IN SA**

*A. cyclops* was promoted in 1970's by the then South Australian Woods and Forest Department for use in sand dune stabilisation works, particularly on the Eyre and Yorke Peninsulas. The species was occasionally used as an ornamental species prior to this larger scale promotion. *A. cyclops* has been in cultivation in SA since at least the late 1950s (Mulvaney 1991).

#### **ORIGINS**

*A. cyclops* is native to the southern and south-western coasts of Western Australia, and some parts of western SA (Cowan and Maslin 2001). In SA Cowan and Maslin (2001) considered it indigenous to coastal, western SA and the Yorke Peninsula. However, there is contention as to whether it is indigenous to the lower Eyre, Yorke and Fleurieu Peninsula or Kangaroo Island (Cowan and Maslin 2001, R. Taylor pers comm., B. Overton pers. comm.).

#### **INVASIVENESS**

##### **Naturalisation history**

Within SA. *A. cyclops* is indigenous to the Nullarbor and Eyre Peninsula (north-west coast) botanical regions of SA, at least to Fowlers Bay (M. O'Leary pers. comm.). It started to be collected from the 1970s from coastal areas on the south and eastern Eyre, Yorke and Fleurieu Peninsulas, in the Adelaide region and on Kangaroo Island (M. O'Leary pers comm.). The rate at which *A. cyclops* is spreading on central and eastern SA coasts, combined with no early herbarium records, suggests that these populations may have originated from plantings. Counter to this argument is the apparent expansions in local abundance and range in the last century of various other Acacias such as *A. pycnantha*, *A. paradoxa* and *A. longifolia* ssp. *sophorae* (M. O'Leary pers. comm.). Regional experiences and observations of spreading *A. cyclops* are as follows:

*Adelaide Hills* – Seedlings from a (now dead) *A. cyclops* windbreak on a Monarto farm continue to be regularly removed (J. Bollard pers. comm.)

*Adelaide* – Present at R. B. Conelly Reserve, North Haven (P. Tucker pers. comm.), *Eucalyptus porosa* remnant in Playford (K. Mercer pers comm.), Shepherd's Hill RP and Hallet Cove CP (E. Robertson pers. comm.). Was widespread in Marino CP until controlled in the late 1990s. Seedlings are still being removed regularly (E. Robertson pers. comm.).

*Fleurieu* – *A. cyclops* is non-indigenous to the Southern Lofty Botanical Region (M O’Leary pers. comm.). Occurs on roadsides at Strathalbyn and Milang, along the waterfront at Clayton and large infestations on Hindmarsh Island (N. Mallen pers. comm.). Areas of regeneration are around the mining site at Rapid Head, along the southern Fleurieu dunes from Victor Harbor to Goolwa and on the dunes in Carrickalinga and Normanville (R. Taylor pers. comm.). Weedy at Port Willunga and Maslins Beach in sand dunes (R. Chapman pers. comm.).

*Kangaroo Island* – There is contention over the indigenous status of *A. cyclops* here. It is very common along the north-eastern coastal areas of Kingscote to Big Brownlow and extending towards the Cygnet River estuary (K. Moritz and B. Overton pers. comm.). The first herbarium specimen for Kangaroo Island is dated at 1945 with all specimens from then until 1985 being collected from the Kingscote/Big Brownlow area, near areas of human settlement. Plantings of unnamed wattles had occurred on the Kingscote foreshore in 1936 as part of the centenary of settlement of SA celebrations. A more distant herbarium specimen was recorded from Murray Lagoon in 1992 with the notes ‘Apparently rare...slender trees to 5 m high’. This could be a recent arrival, or it could be a rare, indigenous population. This part of the island also has other arid species, including the only known population of *Melaleuca cuticularis* in SA, which co-occurs with *A. cyclops* in Western Australia (M. O’Leary pers. comm.). Whether indigenous or not, *A. cyclops* is increasing in density in foreshore areas around Kingscote, with subsequent declines in other plant species.

*Lower Eyre Peninsula* – *A. cyclops* has been introduced into coastal areas and is rapidly colonizing some areas, with large infestations in near-coastal to dune areas in the Coffin Bay region (L. Bebbington, S. Bey pers. comm.). Given its late appearance in herbarium records in comparison to much earlier records of *A. longifolia* var. *sophorae* and *A. retinoides* var. *uncifolia*, *A. cyclops* is likely to be non-indigenous here (M. O’Leary pers. comm.).

*Upper Eyre Peninsula* – Large plants of *A. cyclops* are present along sand dunes at Elliston (author).

*Yorke Peninsula* – *A. cyclops* is doubtfully native to here, given its first recording near Port Wakefield in 1970 despite extensive collecting on the Peninsula by B. Copley (M. O’Leary pers. comm.). An extensive stand has been planted at Foul Bay on the southern end of the Peninsula and seedlings from these trees are being transplanted to nearby sites (authors). At Cape Elizabeth, a large coastal infestation is being controlled by the local Council (H. Longbottom; R. Adair pers. comm.). It is also found in remnant vegetation at Tiddy Widdy Beach (R. Taylor pers. comm.) and Stansbury (H. Longbottom pers. comm.).

Figure 13 shows reported locations of *A. cyclops* in SA, categorised into indigenous and naturalised populations, and populations with unknown origins.

Within Australia. *A. cyclops* has naturalised in Victoria on the west coast of the state and in eastern Melbourne (AVH 2001).

Internationally. *A. cyclops* has naturalised in southern California (CalFlora 2001) and Portugal (Flora Europaea 2001). The species is a widespread invader of native vegetation in southern and western South Africa (Henderson 1995).

### **Establishment**

*A. cyclops* seeds weigh approximately 25 mg per seed (Gill 1985), excluding the fleshy aril (see Dispersal below). Despite a high degree of hard-seededness at maturity (approximately 75%), measurements in South Africa found a rapid decline in seed viability once in the soil. In the first year 97% of seeds rotted or germinated, but the <3% remaining were likely to persist in the soil for many years (Holmes 1989a). Whilst fire may promote germination of these long-lived seeds in the soil, it is clear that *A. cyclops* readily establishes in the absence of fire; natural populations in Western Australia appear to be rarely subject to fire (Gill 1985 quoting Christensen and Kimber 1975).

In South Africa, *A. cyclops* is one of that country's most serious and widespread invasive weeds, forming thickets in fynbos (i.e. heath vegetation), dunes, forest gaps and watercourses (Henderson 1995). In SA, *A. cyclops* has been observed establishing within open mallee and coastal dune vegetation. In Western Australia, *A. cyclops* is commonly associated with vegetation that has been disturbed by either natural events (e.g., sand dune movement) or by human disturbance (e.g., trampling, vehicle tracks) (Gill 1985). *A. cyclops* has a high requirement for light and will not persist in deep shade (Duke 1983).

### **Reproduction**

*A. cyclops* can produce seeds within two years from germination (H. Lamont pers. comm.). An annual seed fall of >1000 seeds/m<sup>2</sup> has been measured in South Africa (Milton and Hall 1981). This species does not reproduce vegetatively.

### **Dispersal**

*A. cyclops* has been observed to have spread relatively rapidly in parts of SA (N. Mallen and B. Overton pers. comm.). This is probably a result of efficient bird dispersal; *A. cyclops* seed is spread long-distances by birds attracted to the oil-rich, red, aril or funicle which encircles each seed in the pod. In Australia, birds which have been observed dispersing *A. cyclops* seed include silvereyes, red wattlebirds, grey currawongs, singing honeyeaters, brush bronzewing pigeons and magpies (Gill 1985). *A. cyclops* germination is enhanced by seed passage through the gut of birds (Glyphis et al. 1981). *A. cyclops* is also spread by birds in South Africa (Glyphis et al. 1981) and a clumped distribution pattern of the species is associated with tall plants as a result of birds defecating at these perch sites. Similar observations have been made in SA (N. Mallen, B. Overton, H. Longbottom, K. Mercer pers. comm.), with seed having been dispersed from several hundred metres to several kilometres from seed-bearing *A. cyclops*.

Spread of *A. cyclops* seed may be enhanced by the persistence of open pods on bushes for at least 1-2 years (Gill 1985, Milton and Moll 1982). Seeds are prominently held in open pods, providing a long period for bird dispersal. Ants also disperse the seed over short distances (Gill 1985, Holmes 1990). They collect shed seed from the soil surface, using the aril as a food source and burying the seed in the process. Holmes (1990) considered that ants play a critical role in maintaining and accumulating acacia seedbanks and hence facilitate development of dense stands.

In SA, *A. cyclops* was seen occasionally growing in drainage lines on roadsides, indicating probable spread by graders.

## IMPACTS

### Density

*A. cyclops* appears to be expanding its density in various coastal locations in SA; on the Eyre, Yorke and Fleurieu Peninsulas and on Kangaroo Island. Amongst open vegetation on Kangaroo Island there was around 0.5-1 seedlings per m<sup>2</sup>. High density infestations occur (e.g., on Hindmarsh Island) where progressive recruitment has led to dense thickets. Thus it is assumed that *A. cyclops* has the potential to achieve a **high** density in open vegetation types in SA.

### Competitiveness

*A. cyclops* excludes regeneration of most native plants, becomes a dominant biomass component of vegetation and has major impacts on the diversity of groundcover flora. Individual shrubs of *A. cyclops* have a dense canopy that extends from near ground level to their height of 2-4 m (Whibley and Symon 1992). This canopy excludes most other plant species through shading. In addition, a thick ground layer of leaf and pod litter underneath shrubs (to approx. 5 cm depth) is likely to limit establishment of native plants. Seedlings of *A. cyclops* readily establish in close proximity to parent plants, such that canopies merge and a dense thicket results. Leachate from *A. cyclops* leaves and litter has been shown to reduce growth of certain shrubs in South Africa (Rutherford and Powrie 1993).

Coastal species being excluded by *A. cyclops* in the Hindmarsh Island area include *Melaleuca halmaturorum*, *Leucopogon parviflorus*, *Adriana klotzschii*, *Dianella* spp., *Austrostipa* spp., *Pomaderris oraria*, *Pimelea serpyllifolia* and *Kunzea pomifera* (N. Mallen pers. comm.). On Kangaroo Island, *Acacia cyclops* is posing a threat to *Myoporum viscosum*.

### Movement

*A. cyclops* is not spiny and people can penetrate through thickets, albeit at a very slow pace.

### Health risks

There are no known health risks to humans or animals associated with *A. cyclops*.

### Ecosystem health

It is not clear whether *A. cyclops* creates an increased fire risk in native vegetation. There is a build-up of leaf and pod litter on the ground and the canopy reaches down to near ground-level. *A. cyclops* will regenerate from seed after fire, but burning of thickets leads to high levels of seed death unless seed is below 30 mm in soil (Holmes 1989b). By comparison, *Acacia saligna* seedbanks are much more suited to post-fire regeneration (Holmes 1988). Fire is rare in native stands of *A. cyclops* in Western Australia (see

*Establishment* above). In South Africa, *A. cyclops* is most prevalent in strandveld vegetation, which has less frequent fires than in fynbos (Witkowski 1994).

*A. cyclops* is a legume. With a high plant density and plant biomass, it is likely to increase the level of nitrogen fixation in the soil, which will subsequently increase the suitability of the soil for invasion by other nitrogen-responsive weeds.

## POTENTIAL DISTRIBUTION

### Climate tolerances

An analysis of *A. cyclops* distribution in South Africa indicated a preference for sites below 400 m in elevation with annual rainfall of between 500 and 1100 mm (Higgins et al. 1999). However, in Australia the annual rainfall within the natural range of *A. cyclops* is between 200-500 mm (Whibley and Symon 1992).

A climate match for *A. cyclops* was done based on its naturalised distribution in California (CalFlora 2001), Portugal (Flora Europaea 2001) and South Africa (Henderson 1995), and on its native/naturalised distribution in Australia (AVH 2001, authors pers. obs.). This indicated that the whole agricultural zone of southern SA is climatically suitable for naturalisation of *A. cyclops*.

### Soil tolerances

In SA, *A. cyclops* occurs mainly on calcareous sands, shallow calcareous loam or brown calcareous earths (Whibley and Symon 1992). Gill (1985) notes that *A. cyclops* is not confined to calcareous substrates however, and in Western Australia also occurs in acidic soil types such as silicaceous sands, ironstone gravel, heavy red clay and in granite outcrops.

In South Africa, *A. cyclops* is the dominant alien plant of the relatively phosphorus rich strandveld vegetation. Similarly, the coastal calcareous sands where it occurs in Western Australia are higher in phosphorus than the inland acidic soils. However, it was shown that *A. cyclops* does not show a marked requirement for soils with relatively high phosphorus and its distribution may be more indicative of a competitive ability through drought tolerance. (Witkowski 1994)

PIRSA Land Information soil attributes and classes selected for *A. cyclops* were:

- Most Common Soil Groups – calcareous soils, shallow soils on calcrete or limestone, deep sands and highly leached sands; and
- Susceptibility to Waterlogging - rapidly to well-drained.

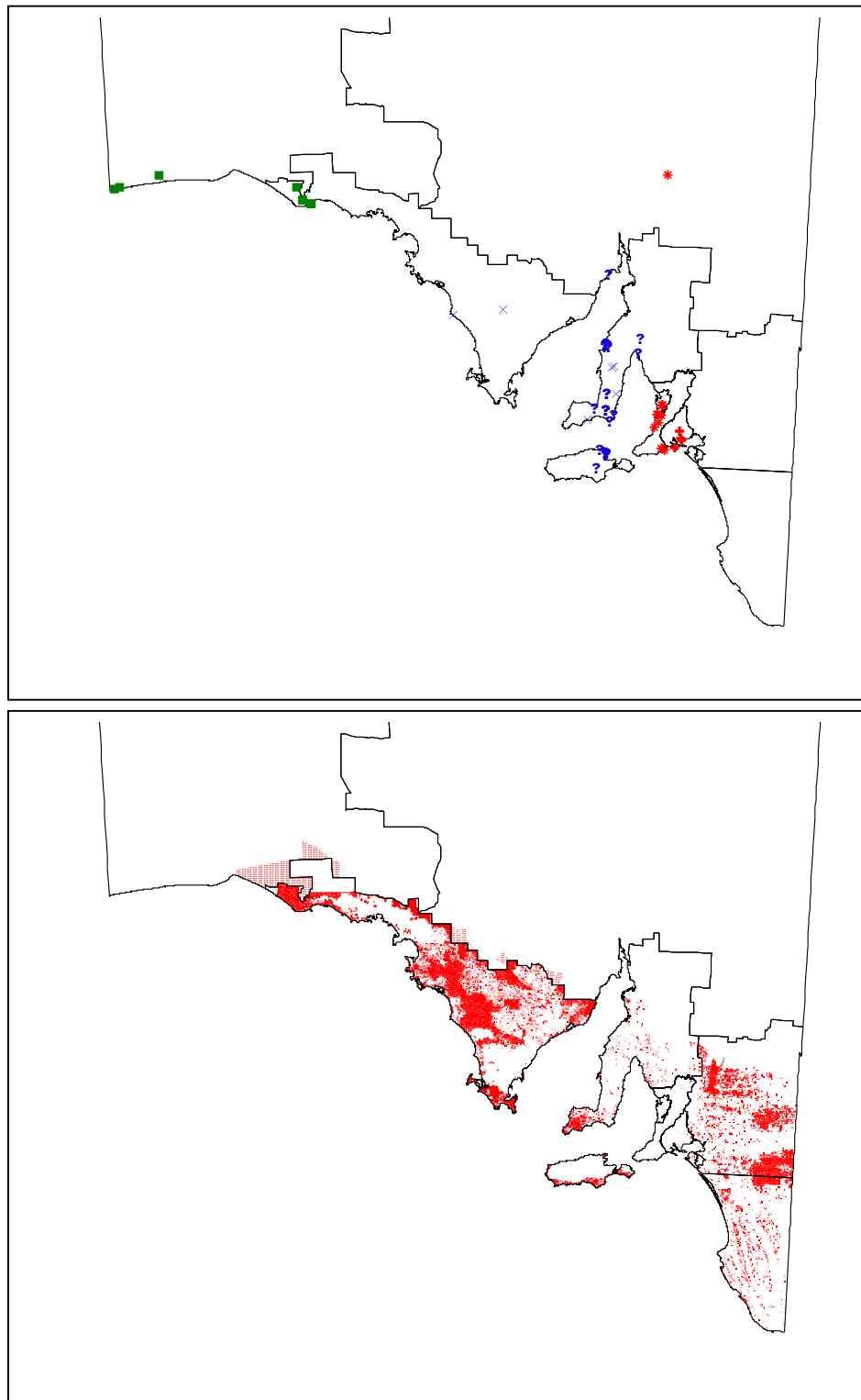
Calcareous sands, calcareous loamy soils, brown calcareous earths and alkaline loam over clay soils (map units A, BB, BG, SV, DD and Lb) were selected from the Atlas of Australian Soils (Northcote et al. 1968) for *A. cyclops* in rangeland areas.

## Areas at risk

The areas and regional proportions of native vegetation in SA suitable for *A. cyclops* are shown in Figure 13 and Table 13 respectively. *A. cyclops* is indigenous to western Eyre Peninsula and hence the species is not considered a potential invader in this region. The indigenous status on Kangaroo Island and Yorke Peninsula is unclear.

**Table 13. Regional proportions of native vegetation suitable for *Acacia cyclops*. Parentheses indicate the species is indigenous and thus the Potential Distribution score becomes zero. “?” indicates the species is questionably indigenous.**

Region	Proportion of native vegetation at risk
Eyre	(86%)
Northern Agricultural Districts	11% ?
Mt Lofty Ranges / Adelaide Metropolitan	4%
Kangaroo Island	26% ?
Murray Darling Basin	45%
South-East	54%
<i>Southern SA - all of above regions</i>	<i>(55%)</i>
<i>Southern SA - excluding Eyre only</i>	<i>20%</i>
Rangeland / Aboriginal Lands	1%



**Figure 13. Known locations of native, questionably native and naturalised *Acacia cyclops* (top) and areas of native vegetation suitable for *A. cyclops* in SA (bottom). Location symbols are: ■ State Herbarium of SA indigenous records, ? State Herbarium of SA questionably indigenous records, \* State Herbarium of SA naturalised records, × Authors questionably indigenous records, + Authors naturalised records.**

## ***Acacia saligna* (Labill.) H.L. Wendl., (Fabaceae)**

### **Golden wreath wattle**

#### **PLANT DESCRIPTION**

*Acacia saligna* is a dense, shrub or small tree which grows to a height of 3-8m (Whibley and Symon 1992, Maslin 2001).

#### **HISTORY OF USE IN SA**

*A. saligna* has been in cultivation in SA since 1860 (Mulvaney 1991), predominantly for use as an ornamental plant. The species has been widely planted around the state, particularly on roadsides and as fence-line windbreaks. *A. saligna* has also been used for sand dune stabilisation and has been direct seeded for rural revegetation works. During the last decade the species has been planted as a fodder tree for livestock.

#### **ORIGINS**

*A. saligna* is native to both coastal and inland south-west Western Australia (AVH 2001).

#### **INVASIVENESS**

##### **Naturalisation history**

Within SA. There are State Herbarium records of naturalised *A. saligna* for the Eyre Peninsula, Murraylands, Yorke Peninsula, Southern Lofty, Kangaroo Island and South-East botanical regions (Jessop 1993). Personal observations of *A. saligna* spreading in SA include:

*Eyre Peninsula* – Has spread from plantings on road reserves along both the east coast as far as the Cowell/Cleve district, and up the west coast as far as Elliston (J. Edwards pers. comm.). Has spread throughout Lock township from a street planting (B. Napier pers. comm.). Spreading from plantings in the Koppio Hills, Wanilla and Wangary areas (S. Bey pers. comm.).

*Yorke Peninsula* – Small patches north of Minlaton. Has been widely planted on Yorke Peninsula by direct seeding (H. Longbottom pers. comm.).

*Mid North* – Present in the Tothill Ranges (A. Prescott pers. comm.).

*Adelaide Hills* – A weed problem in the Mt. Lofty Ranges (P. Clark and J. Wills; A. Allanson; E. Robertson pers. comm.), particularly the Adelaide Hills face (e.g., Auldana) and lower rainfall eastern hills zone (A. Crompton pers. comm.). There is an ongoing control program in the Joe Gappa Reserve, Hillbank, where the infestation originated from a revegetation project in the 1970/80's



(P. Tucker pers. comm.). Invading a *Eucalyptus porosa* woodland remnant at Salisbury Heights, originating from Cobbler Creek RP (R. Taylor pers. comm.).

*Adelaide* – Present in R. B. Conelly Reserve, North Haven (P. Tucker pers. comm.).

*Fleurieu* – Common on roadsides and other public areas in the Milang, Clayton and Strathalbyn areas (authors & N. Mallen pers. comm.). The species has been planted extensively on the rural roadsides of Hindmarsh Island and Cape Jervis and sections of the Yankalilla District including the Normanville sand dunes (R. Taylor pers. comm.). Common around Aldinga and Sellicks (M. O’Leary pers. comm.).

*Kangaroo Island* – Occurs on roadsides and in several areas of native vegetation adjoining areas where it has been planted (K. Moritz pers. comm.).

*South-East* – Frequent on roadsides of Dukes Highway (spreading from plantings), from Tailem Bend to the Victorian border (A. Harvey pers. comm.). Spreading from roadsides into native vegetation in Keith and Bordertown areas and also on edge of Ngarkat CP (G. Cotton pers. comm.). Spread to roadsides from fodder plantings in the Lucindale area, plus many seedlings from mature trees in the Naracoorte area (Z. Stokes pers. comm.). Roadside infestations in the Mt Gambier district (authors).

Figure 14 shows reported locations of *A. saligna* naturalised in SA.

Within Australia. *A. saligna* has naturalised in coastal and inland Victoria, New South Wales and Queensland (AVH 2001).

Internationally. This species has naturalised in southern California (CalFlora 2001), Greece, Spain, France, Italy and Portugal (Flora Europaea 2001). It is a widespread invader of native vegetation in southern and south-western South Africa (Henderson 1995).

## **Establishment**

*A. saligna* seeds weigh approximately 20-30 mg per seed (ATSC 2001). In mediterranean climates (which have hot, dry summers) the majority of seed produced is hardseeded, for example, 90% of seed in South Africa (Holmes 1989a) and 86% in Perth (Tozer 1997). *A. saligna* seed is long-lived in soil; in South Africa 55% of the seed remained ungerminated and viable (i.e. dormant) in the first year of burial, compared to only 3% for *A. cyclops* (Holmes 1989a). Beyond this first year 84% of remaining seed stayed dormant. Holmes (1988) found 100% and 95% seed viability in soil for *A. saligna* after six and eight years respectively at different sites in South Africa. Hot summer fires can break dormancy of *A. saligna* seed leading to a flush of germination. Holmes (1988) observed 70% of viable seed germinating after fire, compared to only 1% after clearing only. However, Tozer (1998) found no effect on dormancy of the *A. saligna* soil seedbank after a (probably) cooler experimental fire in New South Wales. A mature shrub removed from a property on Kangaroo Island still had annual seed germination 12 years later (B. Overton pers. comm.).

Seedling growth of *A. saligna* is rapid, both above and below ground. A deep tap root is quickly developed (Witkowski 1994) to enable survival during summer, particularly in the presence of competing vegetation. Growth is fastest in full sun, but seedlings will establish in partial shade (Muyt 2001). In SA, *A. saligna* has been observed establishing in native

vegetation in the absence of fire. Adjacent to the Dukes Highway west of Keith, *A. saligna* suckers and seedlings have established in dense groundcover of *Kunzea pomifera* (muntries) and various monocots (rushes, *Dianella*). *A. saligna* has also been observed establishing amongst other weeds (e.g., kikuyu (*Pennisetum clandestinum*) adjacent to pine plantations near Mt Gambier).

In south-east Australia, *A. saligna* has established in coastal scrublands and woodlands, grassy woodlands, heathlands, warmer moist forests and riparian areas (Muyt 2001). Similar vegetation types have been invaded in South Africa (Cronk and Fuller 1995).

## Reproduction

*A. saligna* has both sexual and vegetative reproduction. *A. saligna* can commence seeding within 2-3 years from germination. Seed production is high in South Africa. Annual seedfall of 5440 seeds/m<sup>2</sup> and soil seedbank densities of 12000 seeds/m<sup>2</sup> have been measured (Milton and Hall 1981). Seed production in Australia is likely to be lower due to natural predators, even outside the native range of *A. saligna*. The weevil *Melanterius* spp. feeds on developing seeds in eastern Australia (Tozer 1997, New 1983). Soil seedbank densities in New South Wales have ranged from 1400-3600 seeds/m<sup>2</sup> (Tozer 1998). Densities may reach higher levels in SA due to lower summer humidity favouring hardseededness (Tozer 1997).

*A. saligna* suckers following cutting, fire or senescence of an adult stem. Dense stands have arisen on properties where suckers have arisen after physical removal of adult stems (G. Cotton pers. comm.). Some infestations of *A. saligna* observed by the authors in SA did not appear as concentric rings of decreasing stature around a central adult tree. In these cases it was assumed that new plants had established from seed rather than by vegetative spread.

## Dispersal

*A. saligna* is spread long distances by birds, earthworks (e.g., grading) and water (Muyt 2001). None of these dispersal modes are common for *A. saligna* and the vast majority of seeds are shed underneath parent trees (Cronk and Fuller 1995). Ants play a major role in localised dispersal.

*A. saligna* is less adapted to bird dispersal than *A. cyclops*, having a small white aril on the seed and the habit of shedding its pods and seeds in the year of formation. Nonetheless, *A. saligna* is spread by starlings and doves in South Africa (Cronk and Fuller 1995 quoting Boucher and Stirton 1980).

## IMPACTS

### Density

*A. saligna* has been observed to frequently produce seedlings and suckers when planted throughout southern SA. The ability to establish amongst existing vegetation, the presence of seedlings and suckers in close proximity to adult plants and the long-lived soil seedbank all indicate that this species has the potential to reach **high** densities in native vegetation. In undisturbed native vegetation west of Keith, *A. saligna* was observed at

densities of 1-6 stems per m<sup>2</sup>. In Western Australia, *A. saligna* forms dense thickets in the hollows between sand hills in coastal dune systems (Maslin 2001).

### **Competitiveness**

*A. saligna* is a strong competitor. It has rapid root and shoot growth in comparison to other *Acacia* species (Witkowski 1994, Atkin et al. 1998) and high levels of biomass accumulation and litter fall have been recorded (Milton and Siegfried 1981, Milton 1981). In the upper South-East and on the Eyre Peninsula, *A. saligna* was observed forming thickets and out-competing local native species. At the You Yangs Regional Park west of Melbourne it appears to be outcompeting the local *Acacia pycnantha* (G. Carr pers. comm.). It has been observed to compete with other species sown in direct seeding lines, becoming the dominant species (J. Edwards pers. comm.). The canopy of *A. saligna* is more open, narrower and taller than *A. cyclops*, and some understorey species tolerant of partial shading (e.g., *Dianella* spp.) are likely to persist. In South Africa, *A. saligna* tends to exclude shorter shrubs (Holmes and Cowling 1997a) and similar effects on growth of local native shrubs in SA could be expected (e.g., local wattles). After a fire, rapid seedling growth combined with rapid suckering growth from adult plants would significantly interfere with regeneration of native woody species. In South Africa, the diversity and abundance of both standing vegetation and soil seedbanks of native species declines in proportion to the duration of invasion by *A. saligna* (Holmes and Cowling 1997b).

### **Movement**

*A. saligna* thickets observed in SA are more open than those of *A. cyclops*, but the movement of people/animals will be impeded relative to uninvaded native vegetation.

### **Health risks**

There are no known health risks to humans or animals associated with *A. saligna*.

### **Ecosystem health**

*A. saligna* is a legume. At a high density in low fertility soils, it can increase the level of soil nitrogen fixation in native vegetation (Witkowski 1991), increasing the suitability of the soil for invasion by other nitrogen-responding plants such as annual grasses.

In South Africa, the high biomass content of *A. saligna* thickets increases the fuel load for fires. However, the fire risk is tempered by the relatively high moisture content of *A. saligna* foliage (van Wilgen and Richardson 1985). Given trees of similar stature are already present in native vegetation in SA, *A. saligna* is unlikely to increase fire risk.

## **POTENTIAL DISTRIBUTION**

### **Climate tolerances**

A climate match for *A. saligna* was done based on its naturalised distribution in Europe (Flora Europaea 2001) and South Africa (Henderson 1995) and on its native/naturalised distribution in Australia (AVH 2001, authors pers. obs.). This indicated that significant areas of the western, central and south-east agricultural zone of southern SA are climatically suitable for naturalisation of *A. saligna*.

## Soil tolerances

In South Africa, *A. saligna* is the dominant invasive plant on phosphorus poor, sand-plain lowland fynbos (Witkowski 1994). Soil moisture availability at depth appears to be important for survival over summer (Witkowski 1994), and in Western Australia *A. saligna* is associated with watercourses, rivers and creeks (Maslin 1974). However, it is also found on coastal plains and coastal dune systems in Western Australia (Maslin 2000). In SA *A. saligna* occurs on calcareous sands and leached sands with a hardpan (Whibley and Symon 1992). In Western Australia it also grows in acidic sands, moderately heavy clays and podzols (Maslin 1974). It has been observed establishing on a variety of soil types in SA, but in drier areas (e.g., in the Riverland region) the species appears to be restricted to sites with high soil moisture at depth (V. Narbeth pers. comm.).

PIRSA Land Information soil attributes and classes selected for *A. saligna* were:

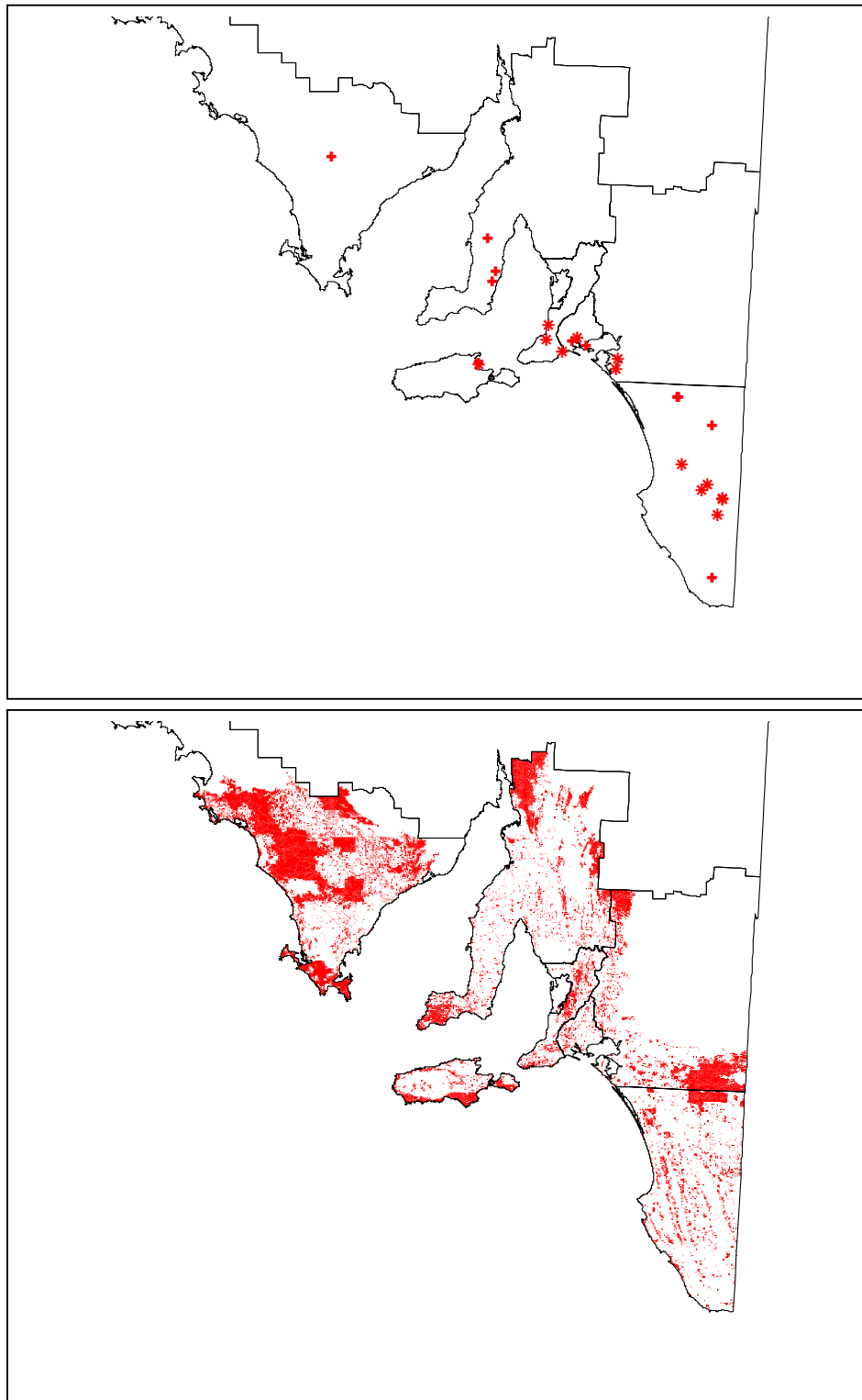
- Susceptibility to Waterlogging – moderately to rapidly well-drained.

## Areas at risk

The areas and regional proportions of native vegetation in SA with potential for invasion by *A. saligna* are shown in Figure 14 and Table 14 respectively.

**Table 14. Regional proportions of native vegetation with potential for invasion by *Acacia saligna*.**

Region	Proportion of native vegetation at risk
Eyre	56%
Northern Agricultural Districts	49%
Mt Lofty Ranges / Adelaide Metropolitan	81%
Kangaroo Island	42%
Murray Darling Basin	23%
South-East	60%
<i>Southern SA (all of above regions)</i>	46%
Rangeland / Aboriginal Lands	0%



**Figure 14. Known locations of naturalised *Acacia saligna* (top) and areas of native vegetation with potential for invasion by the species in SA (bottom). Location symbols are: \* State Herbarium of SA records, + Authors records.**

## ***Atriplex amnicola* Paul G. Wilson (Chenopodiaceae)**

### **River saltbush, Swamp saltbush**

#### **PLANT DESCRIPTION**

*Atriplex amnicola* is a woody, spreading shrub to 1.5 m tall (Wilson 1984).

#### **HISTORY OF USE IN SA**

*A. amnicola* has a similar potential use to *A. nummularia* (see next species) but is not yet widely planted. *A. amnicola* has been the recent focus of an improvement program in Western Australia, which was breeding for productivity, palatability and waterlogging resistance (Galloway et al. 1996).

#### **ORIGINS**

*A. amnicola* is native to coastal and inland areas of central and central-western Western Australia and is associated with creeks and outer margins of salt lakes (Wilson 1984). Note that it is a separate species to *A. rhagodioides* (also called river saltbush), which is native to the Murray River region in eastern SA, north-western Victoria and south-western New South Wales.

#### **INVASIVENESS**

##### **Naturalisation history**

Within SA. *A. amnicola* is currently not recorded as naturalised in SA and has not been observed to spread from plantings.

Within Australia. This species is not recorded as naturalised outside its native range in Western Australia.

Internationally. *A. amnicola* is not known to be naturalised overseas.

##### **Establishment**

The fruits of *A. amnicola* consist of a single seed enclosed in two bracts, similar to the seeds of *A. nummularia*. Fruits weigh around 4 g (Barrett-Lennard and Malcolm 1995). *A. amnicola* has been difficult to establish by direct seeding and there has been some selection work undertaken looking for higher levels of germination and seedling establishment within the species (Malcolm and Runciman 1986). Malcolm and Swaan (1985) found that washing the fruits of *A. amnicola* increased emergence levels of seedlings. Low temperatures also limit germination of *A. amnicola*, with a significant drop occurring from germinating in an 8-15°C to a 4-15°C daily range (Malcolm et al. 1982). *A. amnicola* germination is also reduced by burial, dropping by 50% under 2 mm soil and 95% under 5 mm soil (Barrett-Lennard and Malcolm 1995). The association of *A. amnicola* with riparian areas (see Origins section above), the apparent need for leaching

(similar to *A. nummularia*), and the importance of warm soil temperatures and surface sowing for germination suggests that natural establishment occurs in areas prone to significant disturbance to existing vegetation.

### **Reproduction**

*A. amnicola* is dioecious (i.e. has separate male and female plants) and wind-pollinated. Seed production falls markedly where the proportion of male plants is <10% (Strawbridge et al. 1997). Even with equal numbers of male and female plants, only a 36% seed production has been achieved (Strawbridge et al. 1997). Only 6-20% of fruit collected from wild populations or unmanaged plantations has contained seed (Strawbridge et al. 1996). Seed production in *A. amnicola* is low compared to other revegetation shrubs such as acacias.

Seed set is likely to occur within 3 years of germination. *A. amnicola* can spread by layering, that is, root growth from lateral stems (Wilson 1984), however this is a very slow means of vegetative reproduction.

### **Dispersal**

*A. amnicola* seed is adapted to spread by water.

## **IMPACTS**

### **Density**

It is expected that *A. amnicola* would behave similarly to *A. nummularia* (see next species) and only reach a **low** density in native vegetation if it was to spread from plantings. Establishment would be more likely in the warmer rangelands of SA, in areas subject to flooding.

### **Competitiveness**

At a low density *A. amnicola* would have marginal effects on establishment, biomass and diversity of local native plant species. In a mixed pasture of *A. amnicola*, *Thinopyrum ponticum*, *Puccinellia ciliata* and annual grasses Fuery et al. (1996) observed that *A. amnicola* represented less than 20% of the available fodder at a range of shrub densities. This indicated that it is not strongly competitive.

### **Movement**

*A. amnicola* has a more spreading growth form than *A. nummularia*, but at a low plant density in native vegetation it would have negligible impacts on movement of fauna or people in comparison to local native shrubs.

### **Health risks**

There are no known health risks to humans or animals associated with *A. amnicola*.

### **Ecosystem health**

At low densities *A. amnicola* would have no significant effect on ecosystem health.

## POTENTIAL DISTRIBUTION

### Climate tolerances

A climate match for *A. amnicola* was done based on its recorded distribution in Australia (Wilson 1984, AVH 2001). This indicated that northern SA is climatically suited for naturalisation of *A. amnicola*.

### Soil tolerances

*A. amnicola* occurs naturally in areas that are regularly inundated such as floodplains, river channels and lake fringes (Mitchell and Wilson 1994). Whilst it is fairly drought tolerant, this species requires more moist conditions than other saltbushes (Mitchell and Wilson 1994). Growth declines greatly in summer in response to the depth of the water table, especially in sandy soils (Davidson et al. 1996).

Cracking clay soils (map units CC, MM and OO) were selected from the Atlas of Australian Soils (Northcote et al. 1968) for *A. amnicola* in rangeland areas.

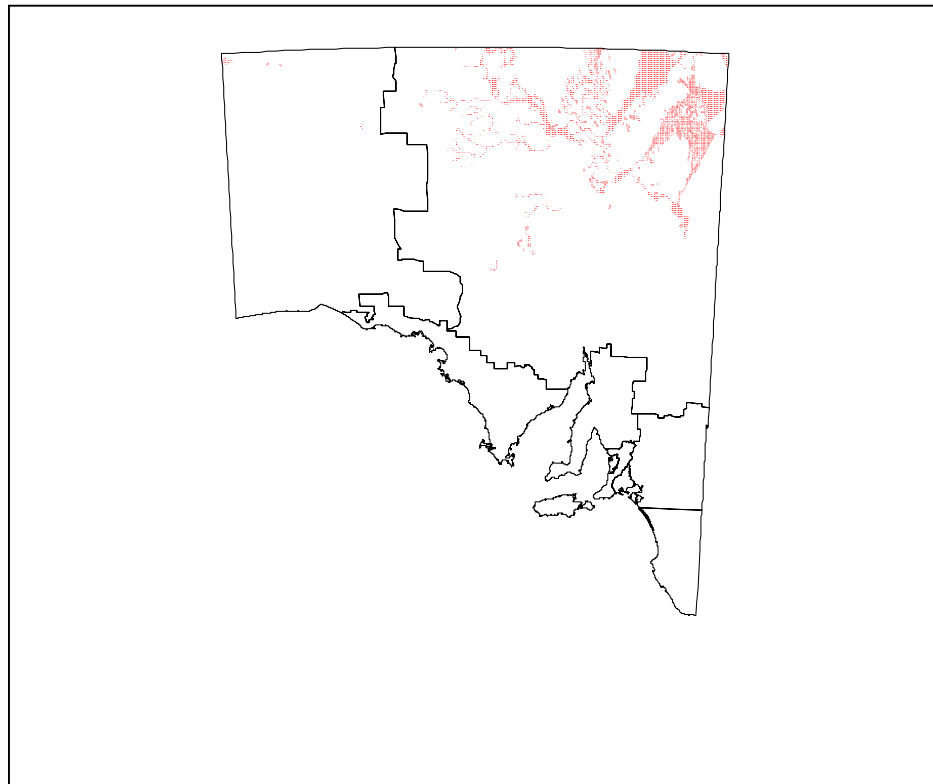
### Soil tolerances

The areas and regional proportions of native vegetation in SA with potential for invasion by *A. amnicola* are shown in Figure 15 and Table 15 respectively.

**Table 15. Regional proportions of native vegetation with potential for invasion by *Atriplex amnicola*.**

Region	Proportion of native vegetation at risk
Eyre	0%
Northern Agricultural Districts	0%
Mt Lofty Ranges / Adelaide Metropolitan	0%
Kangaroo Island	0%
Murray Darling Basin	0%
South-East	0%
<i>Southern SA (all of above regions)</i>	<i>0%</i>
Rangeland / Aboriginal Lands	5%





**Figure 15. Areas of native vegetation with potential for invasion by *Atriplex amnicola* in SA. No locations of naturalised *A. amnicola* were known.**

## ***Atriplex nummularia* Lindley ssp. *nummularia* (Chenopodiaceae)**

### **Oldman saltbush**

#### **PLANT DESCRIPTION**

*Atriplex nummularia* ssp. *nummularia* is a woody, erect shrub that grows to 3m tall (Wilson 1986).

#### **HISTORY OF USE IN SA**

Natural stands of saltbush (*Atriplex* spp.) and other chenopods are used for fodder in rangeland areas of SA. Due to their salt tolerance, saltbushes have been increasingly planted in the southern agricultural zone of SA to provide both fodder and increased water use in areas affected by dryland salinity. They are also grown for fodder on magnesia patches, limestone reefs and non-arable sand dunes (J. Edwards, B. Bartel, A. Knight pers. comm.).

It is difficult to ascertain which of the *Atriplex* species have historically been planted in each of the SA regions without close inspection. There are three *A. nummularia* subspecies (ssp. *nummularia*, spp. *spathulata*, spp. *omissa*) and at least six other *Atriplex* species (*A. amnicola*, *A. undulata*, *A. lintiformis*, *A. sceneria*, *A. rhagodioides* and *A. incrassata*) which have been or are currently being used (sometimes in mixtures) for fodder plantation purposes (H. Lamont pers. comm.). Some are native to the areas where they are planted, however mostly they are planted outside their native range.

#### **ORIGINS**

*A. nummularia* ssp. *nummularia* (referred to below as *A. nummularia*) is 'found in semi-arid and arid regions of central and eastern Australia, often associated with heavy soils or flood plains' (Wilson 1986). Costermans (1981) states that this species mainly forms a 'saltbush scrub associated with black box and mulga woodlands on heavy clay soils of riverine plains of the Murray-Murrumbidgee-Darling system'. In SA, *A. nummularia* is native to the North-western, Lake Eyre, Gairdner-Torrens, Flinders Ranges, Eastern, Northern Lofty and Murray botanical regions.

#### **INVASIVENESS**

##### **Naturalisation history**

Within SA. *A. nummularia* rarely spreads from plantings in SA, particularly in the southern agricultural zone. Fodder plantations occur in many areas of the state and no spread of *A. nummularia* was observed during fieldtrips.

Dispersal from artificially increased densities of *A. nummularia* (i.e. from plantings in its native range) has occasionally been observed in the rangelands. This has occurred south-

east of Yunta where *A. nummularia* is increasing in density along a south running creek (V. Linton pers. comm.). However other plantings in the rangelands have not been seen to spread (M. Horgan pers. comm.) or have struggled to stay alive (D. Powell pers. comm.). Near Cleve on the Eyre Peninsula, seedlings of *A. nummularia* have been seen when stock are removed (I. Honan pers. comm.). However, the species has not been observed to spread from plantings on other parts of the Eyre Peninsula, including at Cowell and Minnipa (H. Lamont pers. comm.). It also does not appear to spread on Kangaroo Island (L. Dohle and author pers. comm.), in the Mid North, especially from large plantings at Port Germein (H. Lamont pers. comm.), on the Yorke Peninsula (H. Longbottom pers. comm.), on the Fleurieu Peninsula (N. Mallen pers. comm.) nor in the South-East of the state (Z. Stokes pers. comm.).

Figure 16 shows reported locations of *A. nummularia* in SA.

Within Australia. *A. nummularia* is not listed as a weed in Lazarides et al. (1997), Carr et al. (1992) or Hussey et al. (1997). At Alice Springs (within its native range) the species has been observed to spread and become dominant in a revegetation area (N. Mallen pers. comm.).

Internationally. *A. nummularia* has been planted for fodder in South Africa (Henderson 1995) and has naturalised across wide areas of the country. It has also naturalised in southern coastal California (Hickman 1996) and Hawaii (Zalba et al. 2000).

## **Establishment**

*A. nummularia* does not regenerate well from seed (B. Bartel pers. comm.). Each seed is enclosed in a bracteole which contains germination-inhibiting chemicals. Leaching and drying (Donaldson 1990, Bartel and Knight 2000), scarification or thrashing (Campbell and Matthewson 1992, Peluc and Parera 2000) or simply ageing of seeds (Edwards 1974) is needed to overcome this dormancy and maximise germination levels. In natural systems this may explain the association of *A. nummularia* with floodplains and creeks as the water flow in these systems provides both leaching and physical damage to the bracteole.

The seeds of *A. nummularia* are relatively large, with an average weight of 3 g/seed (ATSC 2001). Although tolerant to drought when mature, seedlings of *A. nummularia* are susceptible to moisture stress (Verschoor and Rethman 1992). Successful seedling establishment only occurred in moist winters in the upper north region of SA (French and Potter 1975).

In South Africa, *A. nummularia* establishes in semi-arid regions on sandy riverbeds, coastal dunes, edges of clay pans and roadsides (Henderson 1995). In California, the species is found on sandy soils, open disturbed places and coastal bluffs (Hickman 1996). These observations and the need to overcome germination inhibitors, suggests natural establishment is associated with significant disturbance to existing vegetation.

## **Reproduction**

*A. nummularia* is dioecious, therefore plantations established from cuttings may be either male or female stands and produce no seed. Managed grazing by sheep and cattle will limit seed production in mixed gender stands established from direct seeding or from seedlings. Growth of seedlings is rapid and seed set is likely to occur within 3 years of germination. *A. nummularia* has negligible vegetative spread.

## **Dispersal**

Seed of this species is adapted to spread by water.

## **IMPACTS**

### **Density**

Establishment of *A. nummularia* appears to be rare, at least outside its native range in SA. Thus we propose that *A. nummularia* would (at best) only reach a **low** density in native vegetation.

### **Competitiveness**

At a low density *A. nummularia* would have marginal effects on establishment, biomass and diversity of local native plant species.

### **Movement**

*A. nummularia* is a non-spiny shrub. At a low density in native vegetation it would have negligible impacts on movement of fauna or people in comparison to local native shrubs.

### **Health risks**

There are no known health risks to humans or animals associated with *A. nummularia*.

### **Ecosystem health**

The surface soil salinity beneath *A. nummularia* can be increased due to litter fall of leaves containing high concentrations of salt (Sharma and Tongway 1971). However if plants maintain a low density in native vegetation as expected, this would be an insignificant impact at the ecosystem level.

## **POTENTIAL DISTRIBUTION**

### **Climate tolerances**

This species grows best in areas receiving an average annual rainfall of below 375 mm and can grow on deep sands and marginal cropping land (Murphy 1998). On Kangaroo Island, the climate appears too wet for healthy growth, and many planted saltbushes die (L. Dohle pers. comm.). *A. nummularia* has also been observed to not persist in other areas where the rainfall is too high or where the plants have been overgrazed (B. Bartel pers. comm.).

A climate match for *A. nummularia* ssp. *nummularia* was done based on its recorded distribution in Australia (Wilson 1984, AVH 2001). This indicated that the only northern areas of agricultural zone of southern SA are climatically suitable for naturalisation of *A. nummularia*, in addition to rangeland areas.

## Soil tolerances

In its native range it is found on heavy clay soil floodplains (see Origins section above), but has lower waterlogging tolerance than other forage saltbushes.

PIRSA Land Information soil attributes and classes selected for:

- Susceptibility to flooding - >30% of the soil landscape map unit
- Surface soil texture – clay to clay loam.

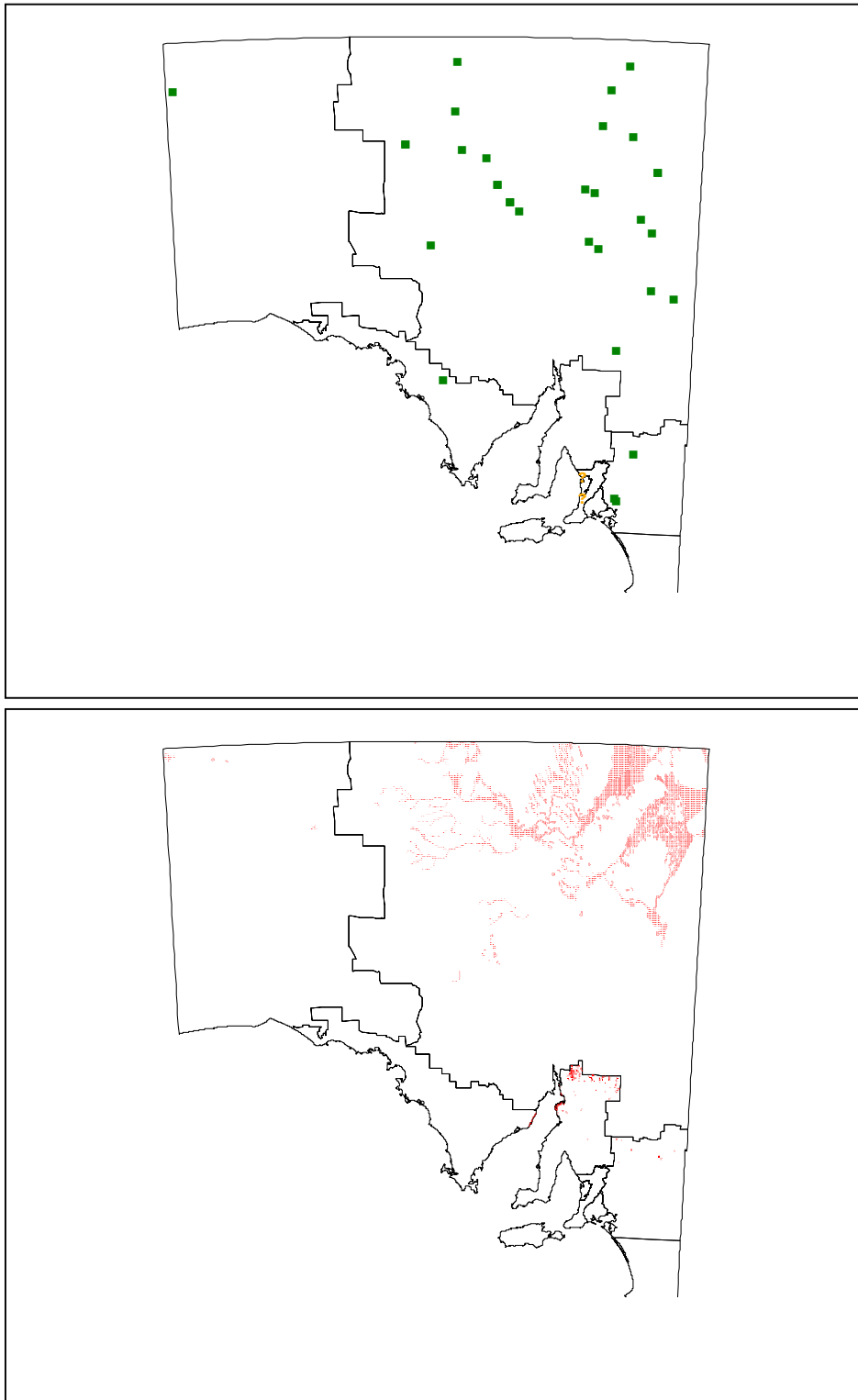
Cracking clay soils (map units CC, MM and OO) were selected from the Atlas of Australian Soils (Northcote et al. 1968) for *A. nummularia* in rangeland areas.

## Areas at risk

The areas and regional proportions of native vegetation in SA suitable for *A. nummularia* spp. *nummularia* are shown in Figure 16 and Table 16 respectively. Note the species is indigenous to the Northern Agricultural Districts (as well as other regions) and hence is not considered a potential invader in this region.

**Table 16. Regional proportions of native vegetation suitable for *Atriplex nummularia* spp. *nummularia*. Parentheses indicate the species is indigenous to the region and thus the Potential Distribution score becomes zero.**

Region	Proportion of native vegetation at risk
Eyre	(0%)
Northern Agricultural Districts	(5%)
Mt Lofty Ranges / Adelaide Metropolitan	0%
Kangaroo Island	0%
Murray Darling Basin	(0%)
South-East	0%
<i>Southern SA - all of above regions</i>	<i>(1%)</i>
<i>Southern SA - excluding indigenous regions</i>	<i>0%</i>
Rangeland / Aboriginal Lands	(5%)



**Figure 16. Known locations of native and naturalised *Atriplex nummularia* spp. *nummularia* (top) and areas of native vegetation suitable for the subspecies (bottom). Location symbols are: ■ State Herbarium of SA indigenous records, ? State Herbarium of SA questionably indigenous records**

# ***Chamaecytisus palmensis* (H.Christ) F.A.Bisby & K.W.Nicholls**

**(Fabaceae) Tagasaste, Tree lucerne**

## **PLANT DESCRIPTION**

*Chamaecytisus palmensis* is a woody shrub or small tree to 4 m tall (Hussey et al. 1997).

## **HISTORY OF USE IN SA**

*C. palmensis* was promoted (unsuccessfully) as a farm fodder plant by the Botanic Gardens of Adelaide in the 1880s (Francisco-Ortega and Jackson 1991) and was frequently available in seed gardening catalogues until approximately 1940 (Mulvaney 1991). The species has been grown as a hedge and as a fodder plant for poultry. Currently *C. palmensis* is being promoted as a fodder shrub on sandy recharge areas, to help reduce water flow into the ground water table and thereby reduce dryland salinity. Large-scale fodder plantations for livestock have been established within the last approximately 15 years.

## **ORIGINS**

*C. palmensis* is native to the Canary Islands (located off the north-west coast of Africa), where it has been cultivated as a fodder shrub for several centuries (Francisco-Ortega and Jackson 1991).

## **INVASIVENESS**

### **Naturalisation history**

Within SA. There are State Herbarium records for naturalised *C. palmensis* in the Southern and Northern Lofty, Kangaroo Island, South-East and Murray botanical regions. The majority of records are for the Southern Lofty region. Personal observations of spread of *C. palmensis* include:

*Adelaide Hills* – Frequent on roadsides; e.g., Mt Torrens (B. Munday pers. comm.), Kangarilla (P. Tucker pers. comm.), Mt Barker to Strathalbyn roadside and Mt Barker to Adelaide railway corridor (authors). Also present in Scott Creek CP (E. Robertson pers comm.).

*Fleurieu* – Victor Harbor roadsides; e.g., Range Road, Waitpinga Road and sections of Hindmarsh Tiers Road (R. Taylor pers. comm.).

*Kangaroo Island* – Some roadsides in the north-east agricultural area (authors).

*Lower Eyre Peninsula* – Few escapees on road reserves in the White Flat district (J. Edwards pers. comm.). Colonising roadsides in the higher rainfall areas of Eyre Peninsula (L. Bebbington pers. comm.). Seedlings observed under the canopy of adult plants at Mount Hill (H. Lamont pers. comm.) at five years after planting.

*Upper Eyre Peninsula* – No spread has been observed from plantings in the Cleve and Cowell districts (J. Edwards pers. comm.).

*South-East* – Occasional spread from plantings on roadsides in the Penola, Naracoorte, Lucindale and Padthaway areas, with infrequent occurrence in native vegetation (authors, Z. Stokes pers. comm., B. Osborne pers. comm.). Does not grow well north of Bordertown due to lower rainfall (J. Samuel-White pers. comm.).

Figure 17 shows reported locations of *C. palmensis* naturalised in SA.

Within Australia. *C. palmensis* has naturalised in WA, Victoria, NSW and Tasmania (AVH 2001).

Internationally. This species has naturalised in Hawaii, New Zealand, Java and East Africa, probably originating from plants grown in Australia (Francisco-Ortega and Jackson 1991).

### **Establishment**

There is some contention over the invasive ability of *C. palmensis*. Carr et al. (1992) listed it as a very serious threat in Victoria, where it has invaded heath, grassland, woodland, dry-moist sclerophyll forest and riparian vegetation. It is particularly invasive in bushland in higher rainfall areas (G. Carr pers. comm.). However, in SA, *C. palmensis* does not appear to readily establish amongst existing vegetation. Field observations indicate a preference for disturbed sites (e.g., roadsides), with limited overstorey vegetation, a sparse understorey and soil that has been exposed. Only at one site in SA (on Kangaroo Island) were *C. palmensis* seedlings found in dense roadside vegetation. *C. palmensis* establishment is associated with disturbance in Western Australia (Hussey et al. 1997), near Frankston in Victoria (I. Faithfull pers. comm.) and in New Zealand where its habitat is road-side banks, dry coastal hillsides, dry waste places and river-beds (Roy et al. 1998).

In SA, roadside patches of *C. palmensis* adjacent to plantings have not substantially spread for several decades (D. Cranwell, N. Mallen, Z. Stokes pers. comm.) and appear to persist through self-replacement or continued seed rain from plantings (Z. Stokes, J. Jessop pers. comm.). *C. palmensis* is rarely seen invading relatively intact native vegetation (A. Crompton, R. Taylor pers. comm.). Seedlings were rarely observed under dense canopies of *C. palmensis* and seedlings subject to some shading often grew away from adjacent plants to seek increased light levels. Similarly, few seedlings establish amongst a dense groundcover. *C. palmensis* fails to establish when planted into perennial veldt grass pasture (Wiley and Seymour 2000). At a Mt Gambier roadside, where *C. palmensis* and Cape broom (*Genista monspessulana*) had been planted together, the broom seedlings outnumbered the *C. palmensis* seedlings approximately 100:1. The broom seedlings had established amongst grasses and weeds on the roadside whereas the *C. palmensis* seedlings appeared to be mainly in the grader line at the road's edge. This indicated a strong difference in establishment ability for two closely related species. An association between roadside grading and *C. palmensis* seedling establishment has also been observed on Kangaroo Island and lower Eyre Peninsula (P. Sheridan pers. comm.). Where mass germination of *C. palmensis* has been observed on an exposed roadside, few seedlings have survived the following summer (R. Taylor pers. comm.).



The underlying mechanisms limiting the germination and seedling establishment of *C. palmensis* are unclear. There are possibly interactions between hard-seededness and the need for hot, exposed soils or scouring through soil movement to break seed dormancy. High levels of germination were observed after Ash Wednesday in Victoria (G. Carr pers. comm.). *C. palmensis* seeds are of comparable size to *A. saligna* and *A. cyclops* seeds, which weigh from 20–30 mg per seed (ATSC 2001). Seeds of this size contain reasonable nutrient reserves for early establishment. However, *C. palmensis* seedlings may be highly intolerant of shading. *C. palmensis* does not originate from a mediterranean climate and seedlings may have poor drought tolerance, which would limit survival during the dry summers which occur in SA.

## Reproduction

Webb and Shand (1985) concluded that *C. palmensis* has a high reproductive effort, with a large floral display, long flowering period, and production of a large number of pods and seeds relative to other mass-blooming legumes. Webb and Shand (1985) also observed self-pollination without insect visitation to flowers. Seed set can occur in the third year of growth (Webb and Shand 1985). In SA, individual *C. palmensis* plants have occasionally been observed with many thousands of seedlings (R. Taylor pers. comm.), of which only a few reach maturity. In general, it appears that seedling establishment rather than seed production limits spread of *C. palmensis*. *C. palmensis* does not have vegetative reproduction.

## Dispersal

Seeds are dispersed in close proximity to parent plants (by explosive release from splitting pods), with some probable further local movement by water. Graders disperse seeds and disturb soil, causing germination along road edges. It has been suggested that seed feeding birds digest the seeds and that sheep may excrete viable seed (M. Norris pers. comm.).

## IMPACTS

### Density

Dense thickets of *C. palmensis* have been observed on roadsides adjacent to plantings. However, no thickets of *C. palmensis* in good quality native vegetation have been identified in SA for this report. This is despite the species being in cultivation in the state for over 100 years. Establishment appears to be rare in undisturbed native vegetation, thus we propose that *C. palmensis* may only reach a **low** density in native vegetation under most circumstances.

### Competitiveness

At a low density *C. palmensis* would only have localised effects on the establishment, biomass and diversity of local native plant species. On a landscape scale the impact would be low, when compared to a high-density invader such as Cape broom (*Genista monspessulana*).

## **Movement**

Individual *C. palmensis* plants have a wide, thick canopy that extends down to near to ground level. Thickets on roadsides can impair movement of people. However, at a low overall density in native vegetation *C. palmensis* would have negligible impacts on movement of fauna or people in comparison to local native shrubs.

## **Health risks**

There are no known health risks to humans or animals associated with *C. palmensis*.

## **Ecosystem health**

At a low density *C. palmensis* is unlikely to cause a major increase in soil nitrogen levels in native vegetation.

## **POTENTIAL DISTRIBUTION**

### **Climate tolerances**

*C. palmensis* seedlings have poor persistence in low rainfall areas (<400 mm annually, B. Bartel pers. comm.), and the species most commonly regenerates in high rainfall areas in SA (e.g., southern Mt Lofty ranges, lower South-East, Kangaroo Island, lower Eyre Peninsula). *C. palmensis* seedlings also do not tolerate frosts (Z. Stokes pers. comm.).

A climate match for *C. palmensis* was done based on its naturalised distribution in Australia (AVH 2001, pers. obs.) and New Zealand, and its native distribution in the Canary Islands (Francisco-Ortega and Jackson 1991). This indicated that the significant areas of the central and south-east agricultural zone of southern SA are climatically suitable for naturalisation of *C. palmensis*.

### **Soil tolerances**

*C. palmensis* does not tolerate waterlogging or alkaline soils (Z. Stokes pers. comm.).

PIRSA Land Information soil attributes and classes selected for *C. palmensis* were:

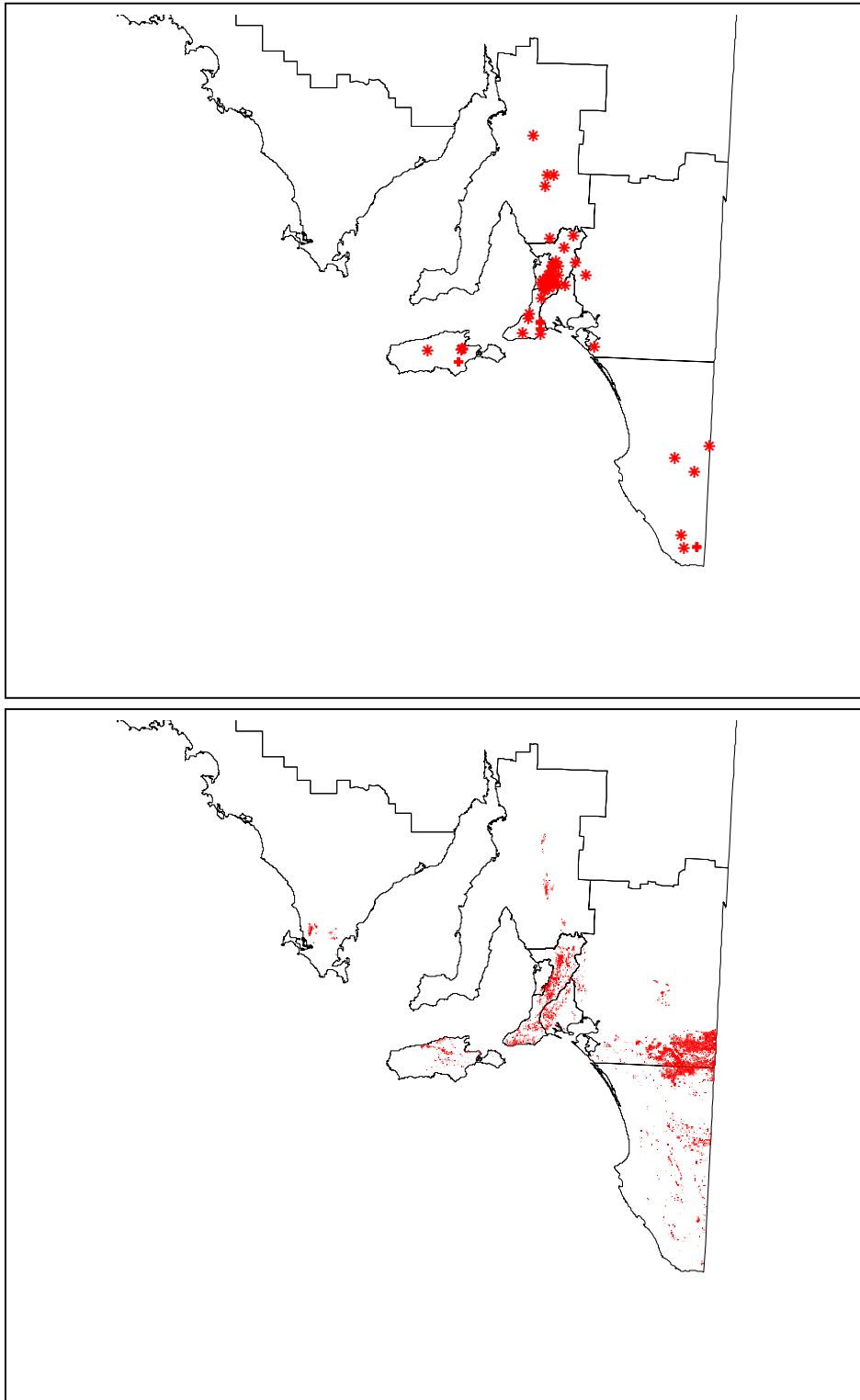
- Susceptibility to Waterlogging - moderately to rapidly well-drained; and
- Alkalinity - non-alkaline surface and subsoil.

### **Areas at risk**

The areas and regional proportions of native vegetation in SA with potential for invasion by *C. palmensis* are shown in Figure 17 and Table 17 respectively.

**Table 17. Regional proportions of native vegetation with potential for invasion by *Chamaecytisus palmensis*.**

Region	Proportion of native vegetation at risk
Eyre	0%
Northern Agricultural Districts	1%
Mt Lofty Ranges / Adelaide Metropolitan	70%
Kangaroo Island	5%
Murray Darling Basin	14%
South-East	24%
<i>Southern SA (all of above regions)</i>	8%
Rangeland / Aboriginal Lands	0%



**Figure 17. Known locations of naturalised *Chamaecytisus palmensis* (top) and areas of native vegetation with potential for invasion by the species in SA (bottom). Location symbols are: \* State Herbarium of SA records, + Authors records.**

## ***Medicago sativa* L. (Fabaceae)**

### **Lucerne**

#### **PLANT DESCRIPTION**

*Medicago sativa* is a perennial herb which grows to 0.5 m tall.

#### **History of use in SA**

*M. sativa* was introduced to SA in 1836, with the first record of naturalisation being in 1948 (Kloot 1986). It has been used as a traditional fodder legume for both hay production and in pasture. *M. sativa* is grown under irrigation and as a dryland pasture. In recent decades there has been increased recognition of the role the species can play in using groundwater and by doing so, reducing the risk of dryland salinity. The species has been widely planted throughout the agricultural zone, although the area under cultivation declined in the late 1970s after aphids decimated stands of the predominant 'Hunter River' cultivar. New cultivars have some aphid resistance. There is currently a research and extension focus to increase the use of dryland *M. sativa* in cereal rotations in southern Australia.

#### **Origins**

*M. sativa* has been in cultivation for over 2000 years (Ragless and Coleman 1971) and is found growing wild across a wide native range, including continental Europe, north Africa and western Asia. It is considered to be native to the area south of the Black Sea and the Caspian Sea (Iversen and Meijer 1967).

#### **INVASIVENESS**

##### **Naturalisation history**

Within SA. *M. sativa* is recorded as naturalised in the Flinders Ranges, Murray and Southern Lofty botanical regions (Jessop 1993). However, Kloot (1986) considered *M. sativa* to be widespread on roadsides in southern SA. For example, it is common along the South-East Freeway/Dukes Highway (T. Reynolds pers. comm.) and is also thick on roadsides near Naracoorte (A. Robins pers. comm.). It is likely to be present in all agricultural areas as a persistent component of pastures. It occurs on ex-grazing land in the Kingscote Heritage Area (where the first SA European settlement in 1836 was located) on Kangaroo Island (B. Overton pers. comm.). The only report received of *M. sativa* being a weed in bushland was from the South-East region (B. Osborne pers. comm.).

Figure 18 shows recorded locations of *M. sativa* naturalised in SA.

Within Australia. *M. sativa* is planted and naturalised in all states of Australia (Lazarides et al. 1997). In Victoria, scattered plants are common on road edges in the North Central,

Glenelg, Goulburn and Port Phillip regions, particularly in sites that catch the maximum water runoff (I. Faithfull pers. comm.).

Internationally. *M. sativa* is widely cultivated in temperate agriculture throughout the world, including North and South America, Europe, Mediterranean Africa, western and central Asia, southern Africa and Australia. In terms of areas with a similar climate to SA, *M. sativa* is naturalised throughout southern Europe (Flora Europaea), California (CalFlora 2001) and South Africa (Wells et al. 1986). Despite being widely planted, there are few records of *M. sativa* being considered a weed of natural areas.

### **Establishment**

*M. sativa* seed is relatively small, at approximately 2- 3 mg/seed (GRIN 2001). Seedling vigour presents difficulties in establishing *M. sativa*, with a need for shallow soil placement and good weed control to allow establishment of the slowly growing seedlings (Humphries and Auricht 2001, Blacklow and Latta 1998). Establishment is particularly slow in autumn and winter, heightening the effects of strong competition from annual winter weeds (Taylor 1987). Seedlings are prone to damage by redlegged earthmites (Condon 1996). These limits on establishment, plus the most frequent naturalised occurrences on roadsides indicate a need for considerable disturbance to existing vegetation for *M. sativa* to establish.

McMahon et al. (1994a) considered *M. sativa* to be essentially non-invasive. They observed establishment on road shoulders, but not in undisturbed, adjoining native vegetation in central-western Victoria. Similarly in SA, *M. sativa* appears to rarely establish in native vegetation.

### **Reproduction**

Under dryland conditions, *M. sativa* seed crops in the Mid North and Upper South-East have yielded 56-220 kg/ha, which is approximately equivalent to 2000-9000 seeds/m<sup>2</sup> (Ragless and Coleman 1971). However, seed production can be significantly constrained by a lack of bee pollinators (Ragless and Coleman 1971). Seed production can occur within the first year of planting.

Conventional *M. sativa* varieties have limited vegetative spread, essentially retaining a crown from which new stems emerge. However, cultivars with creeping lateral roots that produce new shoots and adventitious roots at 10–20 cm intervals have been developed (Humphries and Auricht 2001). Varieties developed by CSIRO have performed poorly in areas with hot, dry summers and under sheep grazing (Humphries and Auricht 2001). Nonetheless, wider use of creeping rooted *M. sativa* would increase the likelihood of invasion into native vegetation.

### **Dispersal**

*M. sativa* plants on roadsides may originally be sourced from uncovered hay loads, with further spread by roadside grading and mowing. *M. sativa* seed remains viable after passing through the gut of horses (van Dyk et al. 2000) and sheep (Da-Lai et al. 1994).

## IMPACTS

### Density

Given that *M. sativa* has been in cultivation for over 100 years in SA and has been generally non-invasive into native vegetation, it is likely to remain at a **very low** density.

### Competitiveness

At a low density *M. sativa* would have marginal effects on establishment, biomass and diversity of local native plant species.

*M. sativa* has been observed to be very persistent, but not very competitive amongst other plants on roadsides. Nonetheless it is being treated as a weed on the Dukes Highway by Transport SA in order to protect the integrity of extensive stands of native grasses. (T. Reynolds pers. comm.)

### Movement

As an herbaceous perennial at a very low density, *M. sativa* would have a negligible effect on movement compared to existing native plants.

### Health risks

*M. sativa* is not poisonous or spiny, and is highly palatable. Thus there are negligible health risks to people or native animals.

### Ecosystem health

*M. sativa* would have no effect at a low density.

## POTENTIAL DISTRIBUTION

### Climate tolerances

*M. sativa* originates from a region with an arid, continental climate of cold winters and hot, dry summers (Iversen and Meijer 1967).

A climate match for *M. sativa* was done based on its recorded distribution in Australia (AVH 2001), Europe (Flora Europaea 2001) and the USA (BONAP 2001). This indicated that the significant areas of the western, central and south-east agricultural zone of southern SA are climatically suitable for naturalisation of *M. sativa*.

### Soil tolerances

*M. sativa* prefers well-drained soils with a pH of 6.0-8.5 (water) (Condon 1996). In its native origin in central Asia, *M. sativa* is a lowland plant occurring in alkaline soils with water at depth (Iversen and Meijer 1967).

PIRSA Land Information soil attributes and classes selected for *M. sativa* were:

- Alkalinity – not strongly alkaline surface and subsoil;
- Susceptibility to acidity - negligible; and

- Susceptibility to Waterlogging - moderately to rapidly well-drained

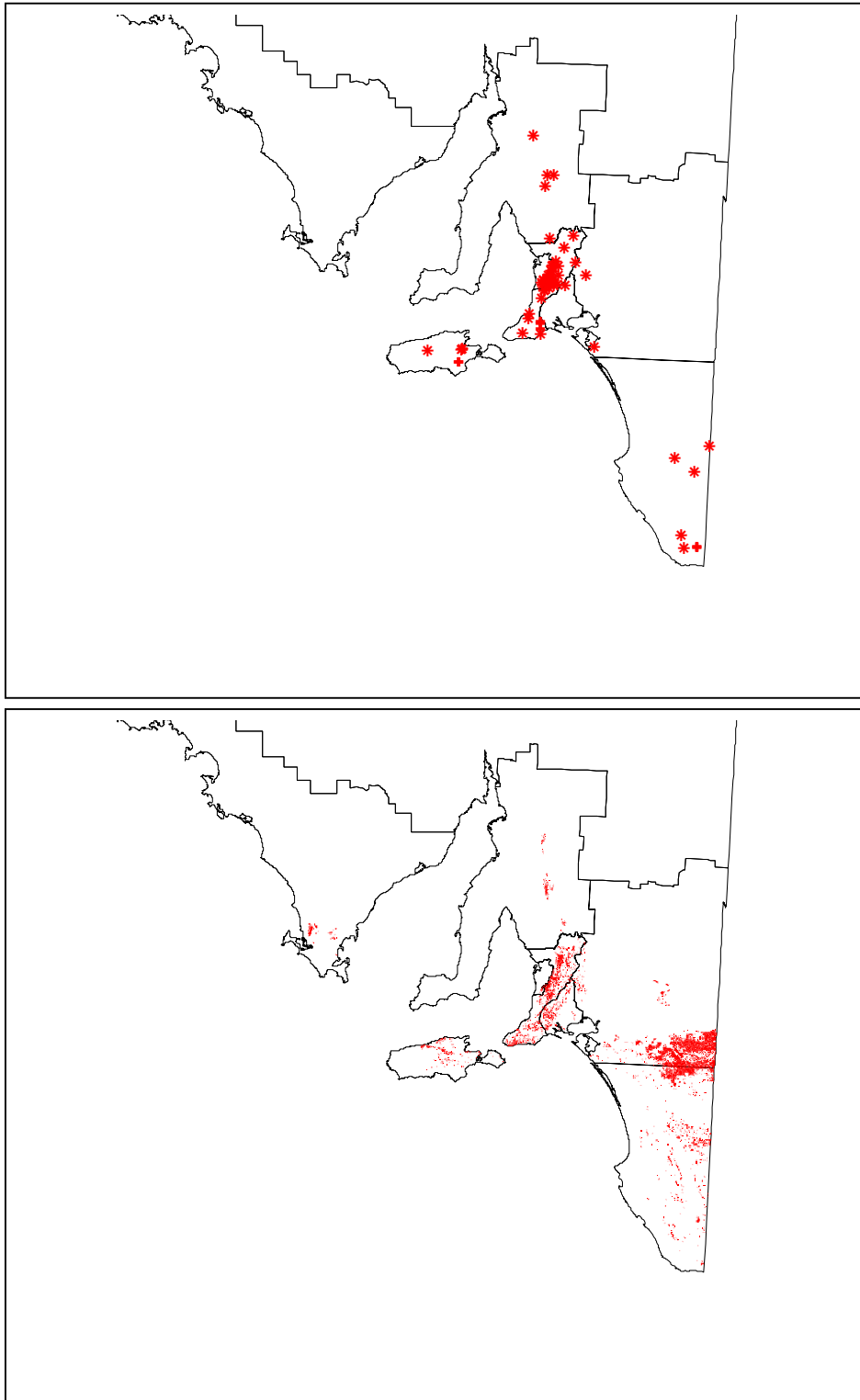
### Areas at risk

The areas and regional proportions of native vegetation in SA with potential for invasion by *M. sativa* are shown in Figure 18 and Table 18 respectively.

**Table 18. Regional proportions of native vegetation with potential for invasion by *Medicago sativa*.**

Region	Proportion of native vegetation at risk
Eyre	6%
Northern Agricultural Districts	28%
Mt Lofty Ranges / Adelaide Metropolitan	6%
Kangaroo Island	0%
Murray Darling Basin	12%
South-East	27%
<i>Southern SA (all of above regions)</i>	13%
Rangeland / Aboriginal Lands	0%





**Figure 18. Known locations of naturalised *Medicago sativa* (top) and areas of native vegetation with potential for invasion by the species in SA (bottom). Location symbols are: \* State Herbarium of SA records.**

## **Weed risk assessment scoring for shrubs**

Figures 19 and 20 show the weed risk assessment scoring for the shrub species across southern SA (all regions excluding Rangelands / Aboriginal Lands). Key criteria scores are summarised in Table 19. Table 20 lists regional Weed Importance scores.

In general terms across southern SA, *Acacia cyclops* and *Acacia saligna* scored as high environmental weed risks (weed importance score between 84 and 209), putting them in the same risk category as the proclaimed plants bridal creeper, boneseed and African boxthorn. *Chamaecytisus palmensis* and *Medicago sativa* scored as low environmental weed risks (weed importance score between 3 and 29) at the southern SA geographic scale. By comparison, the weedy legumes Scotch broom, cape broom and gorse (all proclaimed plants in SA) scored as medium weed risks at this geographic scale. The *Atriplex* species were of negligible weed risk across southern SA (weed importance score <3).

At the regional level, *Acacia cyclops* was a very high weed risk for the MDB, SE and Eyre regions, although it is indigenous to the parts of the latter region. *Acacia cyclops* was a high weed risk for KI and a medium risk for the NAD region, although it is possibly indigenous to parts of these regions. *Acacia saligna* scored as a high to very high weed risk for all southern regions except for the MDB where was a medium weed risk.

The high proportion of native vegetation on well-drained, acidic soils in the MLR region resulted in a high weed risk score for *C. palmensis* in this region. However, with similar climatic and soil preferences but higher impacts, brooms and gorse remain much greater weed threats. *C. palmensis* scored as a low to negligible environmental weed risk elsewhere.

*M. sativa* achieved low weed risk status in the NAD, MDB and SE regions.

WEEDS:	Acacia cyclops	Acacia saligna	Atriplex nummularia	Atriplex amnicola	Chamaecytisus palmensis	Medicago sativa
Western Coastal Wattle	Golden Wreath Wattle	Old Man Saltbush	River Saltbush	Tagasaste	Lucerne	

**REGION:**  
Southern agricultural zone (NHT regions: Eyre, Northern Agricultural Districts, Mount Lofty Ranges, Metropolitan, Kangaroo Island, Murray-Darling Basin, South-East)

**LANDUSE:**  
Native Vegetation  
Assumptions/Comments:  
On average across the state, there is no routine weed management. No stock grazing. No products leaving the landuse. Domestic animals are dogs and horseriding occasionally.

**A) INVASIVENESS**  
Answer all questions with the landuse in mind, except for question 5(a)

1. What is the weed's ability to establish amongst existing plants?  
3 = very high  
2 = high  
1 = medium  
0 = low  
? = don't know

2	2	0	0	1	0
---	---	---	---	---	---

2. What is the weed's tolerance to average weed management practices in the landuse?  
These practices (or lack thereof) can be listed in the above landuse assumptions.  
3 = very high  
2 = high  
1 = medium  
0 = low  
? = don't know

3	3	3	3	3	3
---	---	---	---	---	---

3. What is the reproductive ability of the weed:

(a) Time to seeding?  
2 = 1 year  
1 = 2-3 years  
0 = >3 years / never  
? = don't know

(b) Seed set?  
2 = high  
1 = low  
0 = none  
? = don't know

(c) Vegetative spread?  
2 = fast  
1 = slow  
0 = none  
? = don't know

1	1	1	1	1	2
2	2	1	1	2	2
0	1	0	0	0	0
<b>3</b>	<b>4</b>	<b>2</b>	<b>2</b>	<b>3</b>	<b>4</b>
<b>2</b>	<b>2</b>	<b>1</b>	<b>1</b>	<b>2</b>	<b>2</b>

**TOTAL:**  
**SCORE FOR 3:**  
3 = total of 5 or 6  
2 = total of 3 or 4  
1 = total of 1 or 2  
0 = total of 0

4. How likely is long-distance dispersal by natural means:

(a) Flying birds?  
2 = common

(b) Other wild animals?  
1 = occasional

(c) Water?  
0 = unlikely

(d) Wind?  
? = don't know

2	1	0	0	0	0
0	0	0	0	0	?
1	1	1	1	1	1
0	0	0	0	0	0
<b>3</b>	<b>2</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>
<b>2</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>

**TOTAL:**  
**SCORE FOR 4:**  
3 = total of 6 to 8  
2 = total of 3 to 5  
1 = total of 1 or 2  
0 = total of 0

5. How likely is long-distance dispersal by human means:

(a) Deliberate by people? (ignore landuse)  
2 = common

(b) Accidentally by people?  
1 = occasional

(c) Contaminated produce?  
0 = unlikely

(d) Domestic/farm animals?  
? = don't know

2	2	2	1	2	2
1	1	0	0	1	1
0	0	0	0	0	1
0	0	0	0	0	1
<b>3</b>	<b>3</b>	<b>2</b>	<b>1</b>	<b>3</b>	<b>5</b>
<b>2</b>	<b>2</b>	<b>1</b>	<b>1</b>	<b>2</b>	<b>2</b>

**TOTAL:**  
**SCORE FOR 5:**  
3 = total of 6 to 8  
2 = total of 3 to 5  
1 = total of 1 or 2  
0 = total of 0

**TOTAL INVASIVENESS SCORE:** **11 10 6 6 9 8**

Figure 19. Invasiveness scoring for the shrub species using the Weed Importance Scoresheet.

		<i>Acacia cyclops</i>	<i>Acacia saligna</i>	<i>Atriplex nummularia</i>	<i>Atriplex armicola</i>	<i>Chamaecytisus palmensis</i>	<i>Medicago sativa</i>
<b>WEEDS:</b>		Western Coastal Wattle	Golden Wreath Wattle	Old Man Saltbush	River Saltbush	Tagasaste	Lucerne
<b>B) IMPACTS</b>							
Assume the average weed management practices have not changed to specifically target the weed, and it has spread across/along a whole paddock, orchard, plantation, nature reserve or water body. If the weed is well-controlled by these average practices then it will occur at a low density and will have minimal impacts.							
<b>What density would the weed achieve?</b>		L = LOW M = MEDIUM H = HIGH					
		H	H	L	L	L	L
1. Does the weed reduce the establishment of desired plants?	3 = > 50% reduction 2 = 10-50% reduction 1 = < 10% reduction 0 = none ? = don't know	3	2	0	0	1	0
2. Does the weed reduce the mature yield or amount of desired vegetation?	4 = > 50% reduction 3 = 25-50% reduction 2 = 10-25% reduction 1 = < 10% reduction 0 = none ? = don't know	4	2	0	0	1	1
3. Does the weed reduce the quality of products or services obtained from the landuse?	3 = high 2 = medium 1 = low 0 = none ? = don't know	2	2	0	0	1	0
4. Does the weed restrict the physical movement of people, animals, vehicles and/or water?	3 = high 2 = medium 1 = low 0 = none ? = don't know	2	2	0	0	1	0
5. Does the weed affect the health of animals and/or people?	3 = high 2 = medium 1 = low 0 = none ? = don't know	0	0	0	0	0	0
6. Does the weed have major, positive or negative effects on environmental health:							
(a) food/shelter?		0	0	0	0	0	0
(b) fire regime?	-1 = major positive effect	?	0	0	0	0	0
(c) increase nutrient levels?	1 = major negative effect	1	1	0	0	0	0
(d) soil salinity?	0 = minor or no effect	0	0	0	0	0	0
(e) soil stability?	? = don't know	0	0	0	0	0	0
(f) soil water table?		0	0	0	0	0	0
<b>TOTAL:</b>		1	1	0	0	0	0
<b>SCORE FOR 6:</b>		1	1	0	0	0	0
3 = total of 4 to 6 2 = total of 2 or 3 1 = total of 1 0 = total of 0 or less							
<b>TOTAL IMPACTS SCORE:</b>		12	9	0	0	4	1
<b>C) POTENTIAL DISTRIBUTION</b>							
In the Board, what area of the landuse is suitable for the weed?		10 = 95-100% of landuse, 9 = 85-95%, 8 = 75-85% 7 = 65-75%, 6 = 55-65% 5 = 45-55%, 4 = 35-45% 3 = 25-35%, 2 = 15-25% 1 = 7.5-15%, 0.5 = 1-7.5% 0 = <1%, ? = don't know					
		2	5	0	0	1	1
<b>WEED IMPORTANCE SCORE</b>							
Scores adjusted to range between 0 and 10							
<b>ADJUSTED INVASIVENESS SCORE:</b>		7.3	6.7	4.0	4.0	6.0	5.3
<b>ADJUSTED IMPACTS SCORE:</b>		6.3	4.7	0.0	0.0	2.1	0.5
<b>POTENTIAL DISTRIBUTION SCORE:</b>		2.0	5.0	0.0	0.0	1.0	1.0
<b>WEED IMPORTANCE =</b>		93	158	0	0	13	3
(Multiplying the scores)							
<b>Number of questions answered as "don't know"</b>		1	0	0	0	0	1

Figure 20. Impacts, Potential Distribution (for southern SA) and Weed Importance scoring for the shrub species using the Weed Importance Scoresheet.

**Table 19. Summary of criterion and final scores for the shrub species for southern SA within the native vegetation landuse. Scoring for other environmental weeds which are proclaimed plants has been included for comparison (APCC data).**

Species	Invasiveness	Impacts	Potential Distribution	Weed Importance
<i>Acacia cyclops</i>	7.3	6.3	2	93
<i>Acacia saligna</i>	6.7	4.7	5	158
<i>Atriplex amnicola</i>	4.0	0.0	0	0
<i>Atriplex nummularia</i>	4.0	0.0	0	0
<i>Chamaecytisus palmensis</i>	6.0	2.1	1	13
<i>Medicago sativa</i>	5.3	0.5	1	3
<b>Proclaimed:</b>				
<i>Asparagus asparagoides</i> (Bridal creeper)	7.3	3.7	6	162
<i>Chrysanthemoides monilifera</i> spp. <i>monilifera</i> (Boneseed)	7.3	4.7	4	139
<i>Cytisus scoparius</i> (Scotch broom)	7.3	5.8	1	42
<i>Euphorbia terracina</i> (False caper)	5.3	1.1	4	23
<i>Genista monspessulana</i> (Cape broom)	7.3	6.3	1	46
<i>Lycium ferocissimum</i> (African boxthorn)	6.7	4.2	6	169
<i>Marrubium vulgare</i> (Horehound)	6.7	1.1	4	29
<i>Rubus fruticosus</i> agg. (Blackberry)	7.3	6.3	1	46
<i>Ulex europaeus</i> (Gorse)	6.0	5.8	1	35

**Table 20. Weed Importance scores for the shrub species for different regions. “?” indicates that a species is questionably indigenous to the region.**

<b>Species</b>	<b>Eyre</b>	<b>NAD</b>	<b>MLR/ Metro</b>	<b>KI</b>	<b>MDB</b>	<b>SE</b>	<b>Range /AL</b>
<i>Acacia cyclops</i>	0	46 ?	23	138 ?	230	230	0
<i>Acacia saligna</i>	189	157	252	126	63	189	0
<i>Atriplex amnicola</i>	0	0	0	0	0	0	0
<i>Atriplex nummularia</i>	0	0	0	0	0	0	0
<i>Chamaecytisus palmensis</i>	0	0	88	6	13	25	0
<i>Medicago sativa</i>	1	8	1	0	3	8	0

1. Regions are Eyre, Northern Agricultural Districts, Mt Lofty Ranges / Adelaide Metropolitan, Kangaroo Island, Murray Darling Basin, South-East and Rangeland / Aboriginal Lands.

## RESULTS: GRASSES

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**Photo 10** Dense *Thinopyrum ponticum* on a roadside, having spread from the adjacent paddock, near Spalding , Northern Agricultural Districts. (Photo J.



**Photo 11** *T. ponticum* invading remnant saltmarsh on the shore of Lake Alexandrina, near Milang, Fleurieu Peninsula. (Photo J. Virtue)



**Photo 12** *Ehrharta calycina* invading remnant woodland, near Wanilla, lower Eyre Peninsula. (Photo R. Melland)

## ***Ehrharta calycina* Smith (Poaceae)**

### **Perennial Veldt grass**

#### **PLANT DESCRIPTION**

*Ehrharta calycina* is a perennial grass with flowering stems reaching 30-70 cm high (Jessop 1986b).

#### **HISTORY OF USE IN SA**

*E. calycina* was trialed throughout southern Australia in the 1930's for use as a pasture species. Significant adoption of *E. calycina* as a pasture grass occurred in the upper South-East region of the state, where it gave good growth on low fertility sandy soils (Cook 1946). *E. calycina* has since been widely planted on sandy soils throughout SA. The soil binding properties of *E. calycina* have also led to its use as a dune stabilisation plant in paddocks and on roadside cuttings.

#### **ORIGINS**

*E. calycina* is native to South Africa, where it is widespread across a wide climate range (Chippindall 1955).

#### **INVASIVENESS**

##### *Naturalisation history*

Within SA. There are herbarium records for *E. calycina* in all southern botanical regions of SA (Jessop 1986b), indicating widespread planting and subsequent naturalisation. *E. calycina* is frequent in many open vegetation types on sandy soils across the state. The species is invasive in many conservation areas and in large areas of roadside vegetation. Personal observations of naturalised *E. calycina* include:

*Eyre Peninsula* – *E. calycina* is a major roadside weed in the high and low rainfall areas covering the ground under open mallee vegetation (L. Bebbington, P. Sheridan, B. Napier pers. comm.). It is spreading in Wanilla CP (L. Bebbington pers. comm.).

*Yorke Peninsula* – Occurs in Curramulka, Weetulta and Agery districts and Stansbury scrub (H. Longbottom pers. comm.).

*Adelaide* – A threat to remnant *Callitris gracilis* Low Woodland at Grange Golf Course (M. Turner pers. comm.).

*Adelaide Hills* – Spreading in sections of Belair NP and Scott Creek CP and in good native understorey and roadside vegetation in the Happy Valley area (E. Roberson pers. comm.). Widespread in the Lofty/Barossa and Sturt NPWS Areas (NPWS rangers pers. comm.) Occurs in good quality vegetation in the foothills of the eastern Mt. Lofty Ranges (B. Munday pers. comm.). Occurs in Sandy Creek CP and sandy areas nearby (A. Prescott pers. comm.). Occurs in



*Banksia marginata* remnant vegetation sites near One Tree Hill and Tea Tree Gully (K. Mercer pers. comm.).

*Fleurieu* – *E. calycina* is the main weed problem in Aldinga Scrub CP (authors). It is highly invasive around the Strathalbyn area (N. Mallen pers. comm.). Frequent in Newland Head CP (P. Bulman & M. England pers. comm.) and Normanville sand dunes (R. Taylor pers. comm.).

*Kangaroo Island* – A serious problem of native vegetation, especially in mallee formations and on roadsides (e.g., Moores Rd) in sandier areas (M. Jusaitis pers. comm.). *E. calycina* is common along roadsides in the east of the island (K. Moritz pers. comm.).

*Murray Mallee* – Common in roadside native vegetation (e.g., Taillem Bend to Lameroo, authors pers. obs.). In Pangarinda Reserve at Taillem Bend, and in the Poltalloch Heritage Agreement (M. Jusaitis pers. comm.).

*Upper South-East* – *E. calycina* has been widely planted for pasture and dune stabilisation, and common on roadsides (e.g., between Taillem Bend and Bordertown, Coorong area). It is spreading into native vegetation in the Ki Ki and Coonalpyn areas (T. Reynolds pers. comm.). A problem in Mt Monster CP near Keith (G. Cotton pers. comm.).

*Lower South-East* – A major roadside weed in the region (Z. Stokes pers. comm.) and in bushland (B. Osborne pers. comm.).

Figure 21 shows recorded locations of *E. calycina* naturalised in SA.

Within Australia. *E. calycina* is naturalised in all southern states of Australia. It is widespread in Victoria (Carr et al. 1992) and is highly invasive on the Mornington Peninsula and Longford-Golden Beach-Seaspray areas of Gippsland (I. Faithfull pers. comm.). It is also widespread in WA from Geraldton to Esperance, on sandy soils, on roadsides and in bushland (Hussey et al. 1997).

Internationally. *E. calycina* is widely naturalised on sandy coastal soils in California (CalFlora 2001), and is on the state's list of 'Most Invasive Wildland Pest Plants; Regional' (CalEPPC 1999).

## **Establishment**

*E. calycina* is small-seeded. Seeds are covered in two persistent floral bracts (sterile lemmas) and together weigh approximately 5 mg (Oram 1990). *E. calycina* can germinate over a wide range of temperature and light conditions (Smith et al. 1999), but best establishment in southern Australia is achieved with shallow, autumn sowings (Bowyer 1998).

*E. calycina* is frequently observed to establish on bare ground (Muyt 2001). Native vegetation that has been subject to disturbances such as livestock grazing, fire or soil movement are particularly prone to invasion. However, certain 'naturally open' vegetation types on sandy soils appear susceptible to invasion in the absence of major disturbance (B. Bartel and D. Ancell pers. comm.), albeit at a probably slower rate than significantly disturbed areas. In SA, *E. calycina* is invading open grasslands, mallee and other woodlands and coastal dune systems (authors pers. obs., Muyt 2001, D. Symon, B. Bartel and N. Mallen pers. comm.). It is also invading *E. cladocalyx* (Sugar gum) open forest on

Kangaroo Island and on the lower Eyre Peninsula (authors pers. obs.). In these environments *E. calycina* may be mainly establishing in gaps (e.g., on lichen crusts) where there is no competing vegetation (H. Lamont pers. comm.).

*E. calycina* does not readily invade or persist in relatively pristine, tall, dense vegetation (A. Harvey, R. Taylor, H. Lamont, A. Maguire, I. Honan pers. comm.), possibly due to shading.

## Reproduction

*E. calycina* produces seed in the first year of growth. Seed production is very high over an extended period in late spring. An accumulated soil seedbank of 75,000 seeds/m<sup>2</sup> has been measured in invaded *Banksia* woodland in Western Australia (Smith et al. 1999). *E. calycina* has slow vegetative reproduction with shallow, creeping rhizomes (Jessop 1986b).

## Dispersal

*E. calycina* generally drops seed as it matures but seed is often available for dispersal from flowering stems. The small, softly hairy seeds of *E. calycina* enable them to be dispersed by many means. They readily cling to clothing and probably also animal fur. They can be spread in mud attached to vehicles, animal feet and shoes. They would probably float to enable localised spread by water, but long-distance spread by wind is unlikely. Slashing and grading on roadsides can spread seed (Muyt 2001). Plants have been observed to be associated with horse dung, indicating cut hay as source of dispersal to new regions (E. Robertson pers. comm.).

## IMPACTS

### Density

*E. calycina* has been observed at **high** plant densities in native vegetation on sandy soils in SA.

### Competitiveness

*E. calycina* can have a major effect on the diversity and regeneration of native plants, particularly understorey species.

*E. calycina* grows year round, with slower growth in winter and summer (Freebairn 1989). It is highly drought tolerant and persists (Oram 1990) unless subject to continuous grazing (Freebairn 1989). Infestations can become a dense and dominant component of groundcover vegetation, outcompeting native ground layer species (including native grasses, annuals and perennial herbs), under-storey and tree seedlings and even some larger perennial vegetation (R. Taylor, J. Edwards, I. Honan, B. Bartel, K. Mercer pers. comm.). *E. calycina* also occupies natural gaps between native grasses and shrubs which are occupied by lichens, mosses and fungi and which support some ground foraging bird species (K. Mercer, R. Taylor, M. Blason pers. comm.).

*Eucalyptus incrassata* and *E. fasciculosa* woodlands have been highlighted as vegetation associations under threat from *E. calycina* (N. Mallen, A. Allanson pers. comm.). *E. calycina* is considered a serious weed threat to endangered plants in SA (M. Jusaitis pers.

comm.), for example, the Nationally vulnerable species *Pterostylis arenicola* (Sandhill Greenhood Orchid) (Jusaitis and Smith 1999). In an orchid survey in grasslands in northern Victoria *E. calycina* formed 100% groundcover on sandy rises under *Eucalyptus blakelyi*, *E. melliodora* and *Callitris columellaris* tree cover (G. Carr pers. comm.). Revegetation with native grasses (*Austrostipa* and *Danthonia spp.*) have been unsuccessful in the presence of *E. calycina* (R. Taylor, L. Bebbington pers. comm.).

*E. calycina*'s competitiveness may decline in the longer term, particularly in the absence of further soil disturbance and as shading from overstorey plants increases. On Kangaroo Island, *E. calycina* has been outcompeted in dense vegetation after approximately 5 years (A. Maguire pers. comm.). *E. calycina* has also been observed to be slowly replaced by hardy groundcovers such as *Enneapogon* (N. Mallen pers. comm.) and *Kunzea pomifera* (G. Bishop pers. comm.).

The impact of *E. calycina* may also be reduced where there is a significant kangaroo population, as is found for instance, on Kangaroo Island. At Newland Head CP, on the Fleurieu Peninsula, it is grazed heavily by kangaroos (R. Taylor pers. comm.) *E. calycina* is highly palatable and plants can be killed by intensive grazing (Freebairn 1989). However, frequent grazing may cause soil disturbance, providing conditions for germination and spread of new plants.

### **Movement**

*E. calycina* is not spiny or coarse to touch. It would place similar limits on physical movement to native tussock grasses, so no significant change would occur.

### **Health Risks**

There are no known health risks of *E. calycina* to humans or animals.

### **Ecosystem health**

Invasion of *E. calycina* into shrub-dominated heath and mallee vegetation may cause a long-term increase in fire frequency. In Western Australia, fires have been observed to favour areas where *E. calycina* has invaded heathland and woodland (Baird 1977, Milberg and Lamont 1995). The capacity of *E. calycina* to resprout following fire, its significant germination after fire (Smith et al. 1999) and the rapid accumulation of flammable biomass by the species favours a perpetuation of shorter fire cycles. Shorter fire cycles benefit *E. calycina* but are detrimental to the survival of native species, which are adapted to longer fire cycles.

## **POTENTIAL DISTRIBUTION**

### **Climate Preferences**

*E. calycina* is summer-drought tolerant and will grow in Mediterranean environments with an annual rainfall of around 400 mm or greater (Freebairn 1989). It is also suited to summer-rainfall regions receiving at least 500 mm annual rainfall (Freebairn 1989).

A climate match for *E. calycina* was done based on its distribution in Australia (AVH 2001), South Africa (Chippindall 1955) and California (CalFlora 2001). This indicated that all of southern SA was climatically suitable for *E. calycina*.

## Soil tolerances

*E. calycina* is particularly suited to deep, sandy soils of moderate fertility, both acid and alkaline (Bowyer 1998). It is not suited to heavier loams and clays, and tolerates only temporary waterlogging (Freebairn 1989).

PIRSA Land Information soil attributes and classes selected for *E. calycina* were:

- Surface Texture – sand to sandy loam; and
- Susceptibility to Waterlogging – moderately to rapidly well-drained.

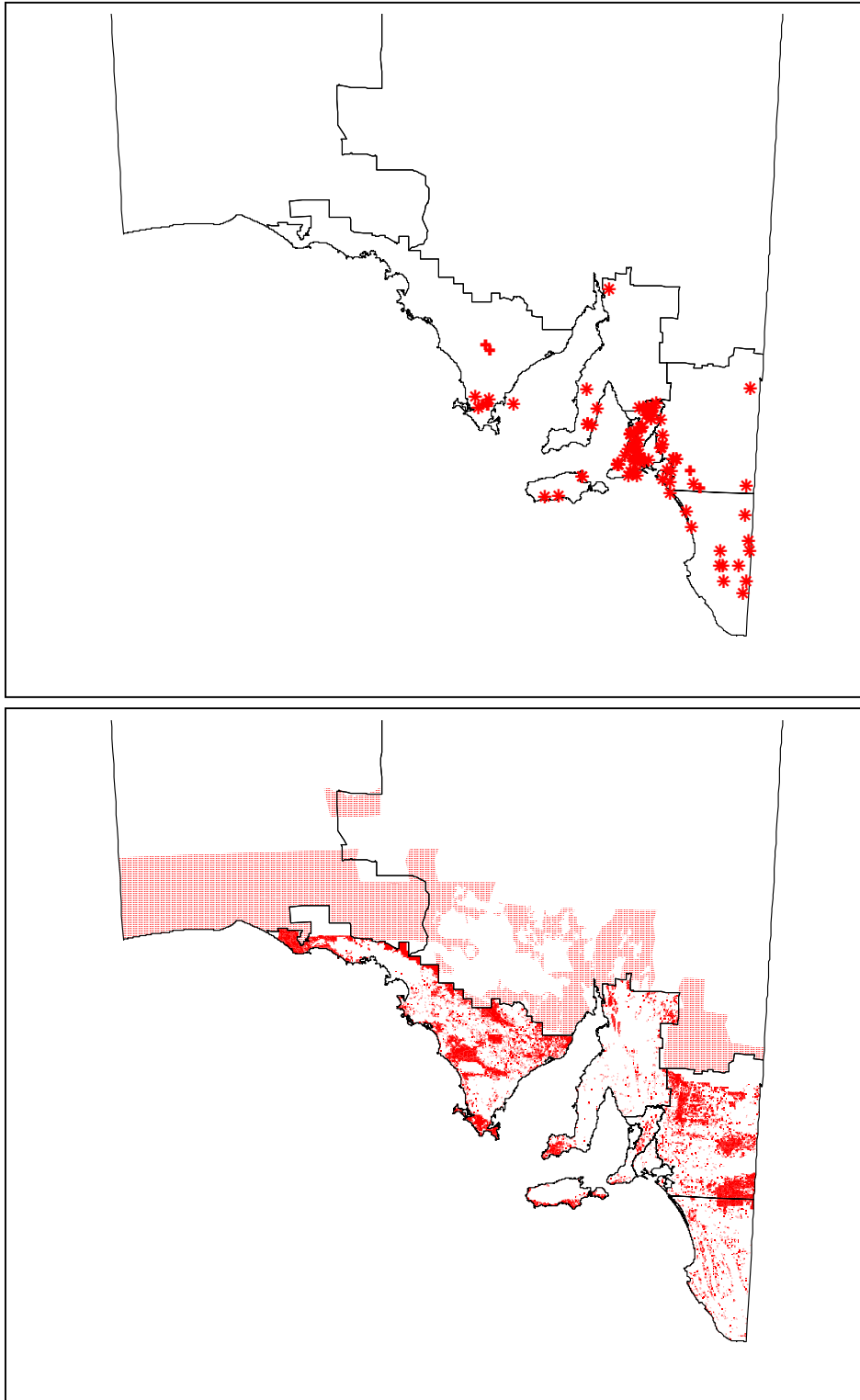
Sandy soils were selected from the Atlas of Australian Soils (Northcote et al. 1968) for *E. calycina* in rangeland areas (map units A\*, B\*, C\*, D\*, E\* and JJ).

## Areas at risk

The areas and regional proportions of native vegetation in SA with potential for invasion by *E. calycina* are shown in Figure 21 and Table 21 respectively.

**Table 21. Regional proportions of native vegetation with potential for invasion by *Ehrharta calycina*.**

Region	Proportion of native vegetation at risk
Eyre	64%
Northern Agricultural Districts	26%
Mt Lofty Ranges / Adelaide Metropolitan	37%
Kangaroo Island	26%
Murray Darling Basin	58%
South-East	56%
<i>Southern SA (all of above regions)</i>	53%
Rangeland / Aboriginal Lands	15%



**Figure 21. Known locations of naturalised *Ehrharta calycina* (top) and areas of native vegetation with potential for invasion by the species in SA (bottom). Location symbols are: \* State Herbarium of SA records, + Authors records.**

## ***Puccinellia ciliata* Bor, (Poaceae)**

### **Puccinellia, Perennial sweet grass**

#### **PLANT DESCRIPTION**

*Puccinellia ciliata* is a cool-season, perennial grass which forms tussocks up to 40 cm high and wide (Barrett-Lennard and Malcolm 1995).

#### **HISTORY OF USE IN SA**

*P. ciliata* was introduced to Australia in 1951 and selected by CSIRO in Western Australia for its ability to establish and persist on severely salted lands (Rogers and Bailey 1963, Oram 1990). It was originally considered to be *P. capillaris*, but was determined as a new species in 1968 (Bor 1968). *P. ciliata* was promoted in SA from 1965 onwards as a salt-tolerant pasture species for areas subject to dryland salinity. (Crawford 1965). The species was planted throughout SA, particularly in the upper South-East and on the lower Eyre Peninsula.

#### **ORIGINS**

*P. ciliata* was originally sourced from the west coast of Turkey (Barrett-Lennard and Malcolm 1995).

#### **INVASIVENESS**

##### **Naturalisation history**

Within SA. There are currently no records of *P. ciliata* in the State Herbarium of SA. *P. ciliata* is reported to have naturalised on the Fleurieu, Yorke and Eyre Peninsulas, Kangaroo Island regions (J. Edwards, P. Sheridan, H. Lamont and K. Moritz pers. comm., authors, Weiller et al. 1995). However, there is also one native species (*P. stricta*) and two other introduced species (*P. distans* and *P. fasciculata*) naturalised in SA (Jessop 1993), and there may be some confusion in identity. Aside from saline pastures, *P. ciliata* has been observed in saline watercourses and wetlands (L. Bebbington pers. comm.).

Within Australia. *P. ciliata* has naturalised in saline areas in WA, NSW and Tasmania (Weiller et al. 1995). It also has naturalised in Victoria (G. Carr pers. comm.).

Internationally. This species is naturalised in New Zealand (Taylor 1980).

##### **Establishment**

*P. ciliata* has relatively small seed, is surface sown and has slow seedling growth; hence it does not readily tolerate weed competition in the first year of establishment (Rogers and Bailey 1963, Hermann and Booth 1997). The genus *Puccinellia* are maritime grasses, and in dryland, non-saline conditions *P. ciliata* behaves as an unthrifty annual, even if irrigated (Rogers and Bailey 1963). Oram (1990) considered it to be a pioneer plant. It does appear

to establish readily on bare ground in saline watercourses, and has been observed spreading into samphire vegetation (authors pers. obs.). However, *P. ciliata* does not readily invade or persist in areas where there is low soil salinity, and is also not highly competitive in samphire vegetation (L. Dohle pers. comm.).

### **Reproduction**

This species can seed in the first spring, following an autumn sowing (Bowyer 1998). There are approximately 6,600 seeds per gram (Oram 1990) and seed yields of 10-20 g/m<sup>2</sup> have been obtained in pastures (Hermann and Booth 1997). Thus seed production is well over 1000 seeds/m<sup>2</sup>/year. *P. ciliata* has no vegetative reproduction.

### **Dispersal**

*P. ciliata* is mainly water dispersed.

## **IMPACTS**

### **Density**

*P. ciliata* has a low competitive ability at the seedling establishment stage. Mature plants are not good competitors in non-waterlogged and/or non-saline situations. Thus *P. ciliata* is likely to only reach a **low** overall density in native vegetation, in saline areas.

### **Competitiveness**

*P. ciliata* has a much more shallow root system than *T. ponticum* (also in this report), to around 30cm deep (Jarwal et al. 1996). It is dormant over summer and quickly re-shoots after opening rains in autumn (Oram 1990), but does not become a large plant. Growth is very responsive to nitrogen fertiliser (Hermann and Booth 1997), indicating a poor competitive ability with other plants. At a low density and with a low competitive ability, *P. ciliata* will have negligible effects on the regeneration, growth or diversity of native plants.

### **Movement**

*P. ciliata* is a small, non-spiky plant and does not significantly impede physical movement.

### **Health risks**

*P. ciliata* is highly palatable and poses no health risks to grazing animals.

### **Ecosystem health**

At a low density, *P. ciliata* is not likely to cause any significant ecosystem changes in native vegetation. In saltmarshes, native samphire (*Halosarcia* spp.) and reeds may provide a similar water-use function.

## POTENTIAL DISTRIBUTION

### Climate tolerances

*P. ciliata* grows best in areas of SA with greater than 350mm annual rainfall (Hermann 1996). It will not tolerate summer waterlogging (Bowyer 1998).

A climate match (temperature and rainfall) for *P. ciliata* was done based on its distribution in Australia (Hermann and Booth 1997, Rogers and Bailey 1963) and Turkey (Weiller et al. 1995). This indicated that all of the southern agricultural zone of SA was climatically suitable for *P. ciliata*.

### Soil tolerances

Soil waterlogging in winter appears to be an essential requirement for persistence. It is highly tolerant of salinity and establishes well on calcareous soils (Bowyer 1998).

The PIRSA Land Information soil attribute selected for *P. ciliata* was:

- Depth to Water Table – 50 cm to above surface for up to 10 months.

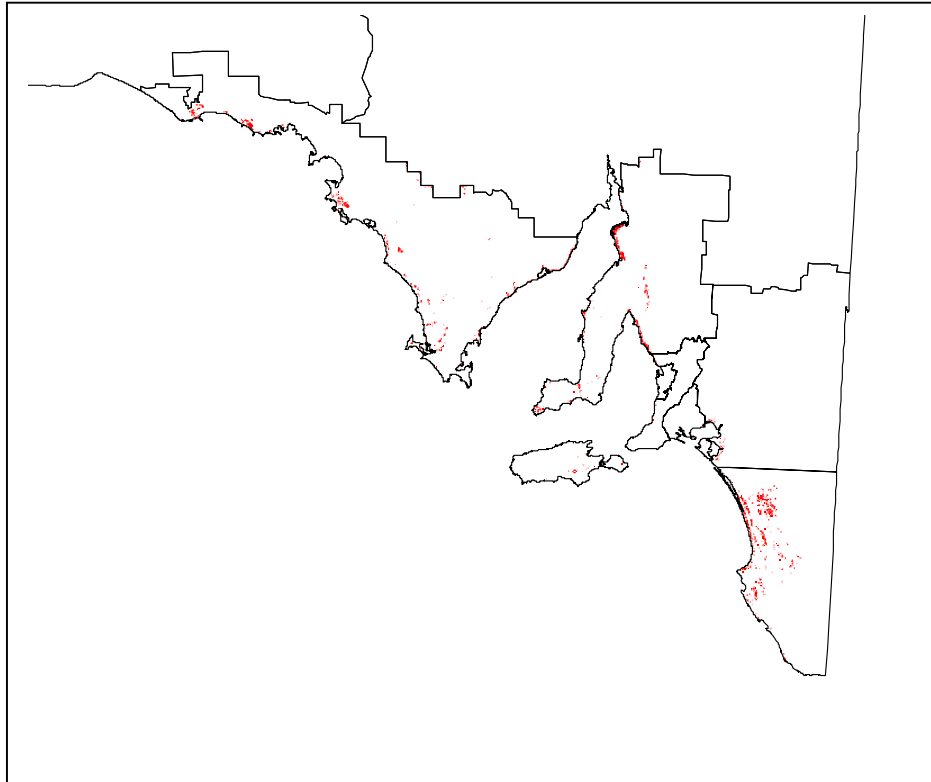
### Areas at risk

The areas and regional proportions of native vegetation in SA with potential for invasion by *P. ciliata* are shown in Figure 22 and Table 22 respectively.

**Table 22. Regional proportions of native vegetation with potential for invasion by *Puccinellia ciliata*.**

Region	Proportion of native vegetation at risk
Eyre	2%
Northern Agricultural Districts	5%
Mt Lofty Ranges / Adelaide Metropolitan	2%
Kangaroo Island	1%
Murray Darling Basin	0%
South-East	13%
<i>Southern SA (all of above regions)</i>	3%
Rangeland / Aboriginal Lands	0%





**Figure 22. Areas of native vegetation with potential for invasion by *Puccinellia ciliata* in SA. No locations of naturalised *P. ciliata* were known.**

## ***Themeda triandra* Forssk. (Poaceae)**

### **Kangaroo Grass**

#### **PLANT DESCRIPTION**

*Themeda triandra* is a perennial grass which grows 30-160 cm tall (Lamp 1990). The name *Themeda australis* was once used for the species in Australia. However, as no taxonomic difference has been found between this and the *T. triandra* found in other parts of the world, the Australian populations are now also referred to as *Themeda triandra* (Jessop 1986b).

#### **HISTORY OF USE IN SA**

*T. triandra* is a dominant native species in temperate, native grasslands on most soil types in Australia (Lamp 1990). Scattered remaining populations of *T. triandra* exist in most regions of SA. Many people are working to conserve and increase the distribution of this species across the state by protecting areas and by using seed in revegetation programs.

#### **ORIGINS**

*T. triandra* is native to all states of Australia (AVH 2001), to Africa and to Asia (Jessop 1986b). Although currently distributed across tropical, sub-tropical and temperate ecoclimates, this C4 species is thought to have originally evolved in a tropical ecoclimate (R. Groves pers. comm.). The species now has a wide distribution across Australia in both wet and dry habitat types (J. Jessop pers. comm.), although it is not found in the alps and in arid areas away from watercourses (Lamp 1990).

#### **INVASIVENESS**

##### **Naturalisation history**

Within SA. There are herbarium records for *T. triandra* in all botanical regions of SA, except for the Nullarbor region (Jessop 1993, AVH 2001). Given that *T. triandra* is a desirable indigenous species across SA, the following personal observations of native/naturalised areas of *T. triandra* include comments on the difficulty of conserving and increasing population spread across areas:

*Eyre Peninsula* – The distribution of *T. triandra* has been markedly reduced due to overgrazing and it would be beneficial to regenerate these areas and encourage its regional spread (B. Bartel pers. comm.). Good stands and roadside patches are still left in many areas (H. Lamont pers. comm.), although destruction by roadworks machinery does occur to these stands (authors). The species has been disturbed through burning in some areas. It has shown good regeneration after burning in the Big Swamp Catchment, near Port Lincoln (J. Edwards pers. comm.). Good stands occur through the

Tod catchment and have been observed along the seasonal watercourses as far north as the Cleve district (J. Edwards pers. comm.), although not in lower rainfall areas (H. Lamont pers. comm.).

*Yorke Peninsula and Mid-North* – It would be good to increase *T. triandra* on the Yorke Peninsula (H. Longbottom pers. comm.). *T. triandra* is a highly desirable native species that occurs in small patches in most NPs and Wildlife reserves in the Southern Flinders District. The rangers in this district aim to commence a revegetation program for this species and promote its regeneration in grasslands in the Southern Flinders reserves, particularly Mt Brown CP and Mt. Remarkable NP (S. Meyer pers. comm.). Landholders are modifying grazing strategies to encourage and regenerate *T. triandra* in their pastures (B. Bartel pers. comm.).

*Adelaide Hills* – As long as this species is collected locally for revegetation, it is a good species to use in revegetation (Andrew Allanson pers. comm.). *T. triandra* is widespread and used in NPWS revegetation programs. It is a low weed risk species, although it may dominate other native grasses (NPWS Cleland District pers. comm.). The species is widespread, is not a weed problem and is used for revegetation by NPWS, the community, ForestrySA and Catchment Water Management Boards (NPWS Lofty/Barossa and NPWS Sturt District pers. comm.).

*Kangaroo Island* – Several recent national herbarium records exist for the Flinders Chase NP.

*All other areas (Fleurieu, Murray Mallee, South-East)* – *T. triandra* is a desirable species, with scattered populations, often under threat of disturbance by roadworks equipment. Ideally the local population's distribution would be increased in these areas (authors, N. Mallen, Z. Stokes, R. Taylor pers. comm.).

Figure 23 shows recorded locations of *T. triandra* in SA.

Within Australia. *T. triandra* is native to all states of Australia (Jessop 1986b).

Internationally. *T. triandra* is native to Africa and Asia (Jessop 1986b). Whilst there are herbicide registrations for *T. triandra* overseas (Randall 2002), no information has been found on the species being considered a significant environmental weed in temperate regions.

### **Establishment**

*T. triandra* weighs approximately 2-4 mg/seed (Loch et al. 1999). *T. triandra* is a summer-active/winter dormant grass and requires warm temperatures (around 25°C) for optimal germination. Hence it establishes in spring and summer in temperate Australia when soil is moist. *T. triandra* does not germinate and establish readily amongst competing grasses and broadleaf herbs. It can form dense stands after fires. (Stafford 1998)

### **Reproduction**

*T. triandra* can set seed within the first year of growth (author pers. obs.). Seed production is relatively low, with measurements of 400/m<sup>2</sup> under light grazing in South Africa (O'Connor and Pickett 1992), 30-95/m<sup>2</sup> in harvesting trials in Queensland (Loch et al. 1999), and <100/m<sup>2</sup> under grazing in Queensland (McIvor et al. 1996). In South Africa,

seed of *T. triandra* does not form a long-lived soil seedbank, with seeds germinating or dying within one year (O'Connor 1997). As this species is an obligate seeder and does not have vegetative reproduction, O'Connor (1997) identified limited seed longevity as a weakness in maintaining *T. triandra* populations.

### **Dispersal**

Seed falls from flowering stems at maturity, so that long-distance dispersal is unlikely.

## **IMPACTS**

### **Density**

In southern Australia *T. triandra* can form dense patches, with little bare ground visible and few other species present at the ground strata (authors pers. obs.). It also frequently occurs at lower densities in a mixture of grasses and native herbs (E. Robertson pers. comm.). The variation in density is a function of shading by trees and shrubs, grazing levels, successional processes, fire regimes and soil properties. A fire frequency of approximately every 5 years is needed to maintain a vigorous, competitive stand of *T. triandra* (Morgan and Lunt 1999), otherwise productivity falls and plants senesce. On a statewide scale average fire frequencies in native vegetation are now much longer than 5 years. Thus we propose that *T. triandra* would only reach a **medium** density on a reserve scale.

### **Competitiveness**

Dense, mature stands of *T. triandra* can significantly suppress the establishment and spread of other grasses (Lunt and Morgan 2000). Morgan (1998) concluded that disturbance to *T. triandra* swards by grazing or burning (every 1-3 years) was needed to optimise seedling recruitment of native herbs, by providing gaps for establishment. However, Morgan and Lunt (1999) also found significant declines in *T. triandra* plant size and density with fire intervals of >6 years. This decline would also allow seedling recruitment of other species. It appears that where dense patches of *T. triandra* are actively maintained then this will limit the regeneration, growth and diversity of other indigenous species. However, with fires now infrequent in native vegetation remnants, *T. triandra* will generally not occur in dense swards and its competitive effects will be minor.

### **Movement**

As *T. triandra* is a native species in almost all regions of the state, the minor limits its perennial tussock form places on movement are a normal feature of the native landscape.

### **Health risks**

*T. triandra* is highly palatable and is not known to have any health risks for animals or humans.

### **Ecosystem health**

As an indigenous component of much of SA's vegetation, *T. triandra* provides food resources to native fauna, particularly larvae of native moths and butterflies

## POTENTIAL DISTRIBUTION

### Climate tolerances

A climate match for *T. triandra* was done based on its distribution in Australia (AVH 2001). This indicated that virtually all of SA was climatically suitable for *T. triandra*. However this may be an overestimate if location records from arid Australia are from adjacent to watercourses.

### Soil tolerances

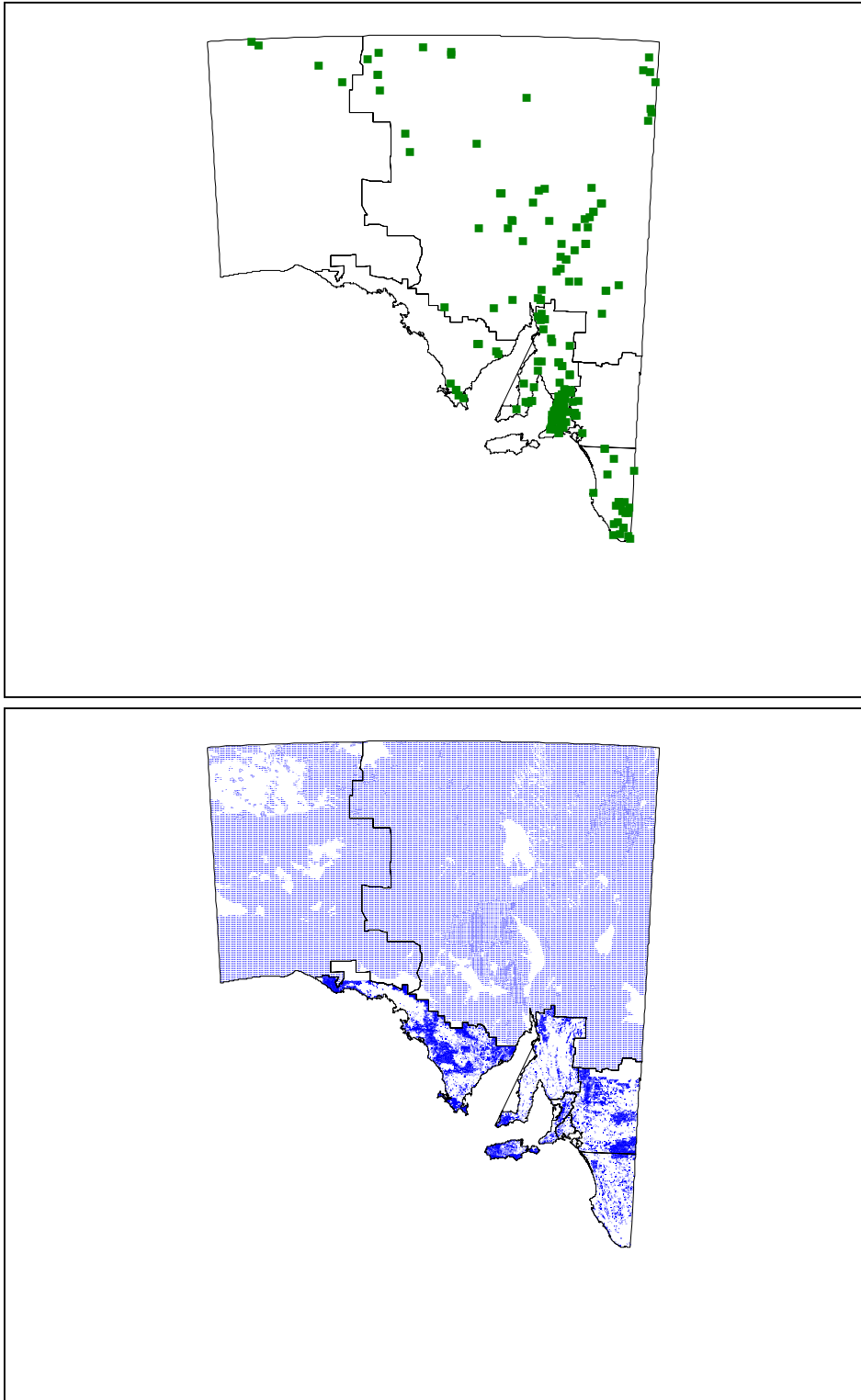
*T. triandra* grows on a wide range of soil types (Lamp 1990), including deep sands (Kooij et al. 1990) and alkaline soils (Fourie and Roberts 1977). Point locations of *T. triandra* populations in SA (data from the State Herbarium of SA) were used to identify common soils from the PIRSA Land Information soil attributes for southern SA and from the Atlas of Australian soils for central and northern SA.

### Areas at risk

The areas and regional proportions of native vegetation in SA suitable for *T. triandra* are shown in Figure 23 and Table 23 respectively. In all of these regions *T. triandra* is indigenous, so it is not considered a potential invader.

**Table 23. Regional proportions of native vegetation suitable for *Themeda triandra*. Parentheses indicate the species is indigenous to the region and thus the Potential Distribution score becomes zero.**

Region	Proportion of native vegetation at risk
Eyre	(84%)
Northern Agricultural Districts	(44%)
Mt Lofty Ranges / Adelaide Metropolitan	(90%)
Kangaroo Island	(67%)
Murray Darling Basin	(60%)
South-East	(72%)
<i>Southern SA - all of above regions</i>	<i>(69%)</i>
<i>Southern SA - excluding indigenous regions</i>	<i>0%</i>
Rangeland / Aboriginal Lands	(90%)



**Figure 21. Known locations of *Themeda triandra* (top) and areas of native vegetation suitable for the species in SA (bottom). Location symbols are ■ State Herbarium of SA indigenous records.**

## ***Thinopyrum ponticum* (Podp.) Z.-W. Liu & R.R.-C. Wang,**

### **(Poaceae) Tall wheatgrass**

#### **PLANT DESCRIPTION**

*Thinopyrum ponticum* is a perennial, densely tufted, summer-growing grass which grows to 1.5 m tall (Jarwal et al. 1996). *T. ponticum* has many scientific synonyms, including:

*Lophopyrum elongatum*

*Elymus elongatus*

*Lophopyrum ponticum*

*Elytrigia elongata*

*Thinopyrum elongatum*

*Triticum elongatum*

*Agropyron elongatum*

#### **HISTORY OF USE IN SA**

*T. ponticum* is an agronomic grass which is used for vegetation cover and/or fodder in saline and highly alkaline areas. The species is also occasionally used for bank stabilisation and for fodder along creeklines. *T. ponticum* was first introduced to SA in 1953 (Kloot 1986, using the synonym *Elymus elongatus*), probably for evaluation purposes. Farm plantings increased in the 1970s, with the development of the cultivar 'Tyrell' in Victoria. *T. ponticum* has been planted in the upper South-East, Mid North and Eyre Peninsula, in areas with a shallow saline water table.

An expansion of use of *T. ponticum* for non-saline areas in southern Australia has been suggested (Smith 1996). Its drought tolerance (conferred by a deep root system), and summer-active growth, indicate a possible alternative to winter-active phlaris (Smith 1996). However, *T. ponticum* requires good management to maintain forage quality for grazing, otherwise it becomes tall and rank with low feed quality and palatability (Smith 1996, Dooley 2001). A new cultivar, 'Dundas', has higher digestibility and productivity than 'Tyrell', with a greater ratio of leaves:stems (Smith and Kelman 2000).

#### **ORIGINS**

*T. ponticum* is native to the Mediterranean region, and to north-west Asia, where it is commonly found on saline meadows and seashores (Asay and Knowles 1985). The Australian cultivar 'Tyrell' originates from a USA variety 'Largo' which in turn originates from seed collected in north-west Turkey. The Australian cultivar 'Dundas' has recently been derived from selected plants of 'Tyrell' and the USA cultivars Largo and San Jose (Smith and Kelman 2000).

## INVASIVENESS

### Naturalisation history

Within SA. There are herbarium records (Jessop 1993) for naturalised *T. ponticum* in the Eyre and Yorke Peninsulas, the Northern and Southern Lofty, and the South-East botanical regions of SA. Personal observations of naturalised *T. ponticum* include:

*Lower Eyre Peninsula* – *T. ponticum* has been observed along the Tod River invading into wetlands (L. Bebbington pers. comm.), and on road verges around saline scalds (P. Sheridan pers. comm.).

*Yorke Peninsula* – Observed on roadsides adjacent to a salt scald planting (author) and in the Warooka area (P. Tucker pers. comm.). Also occurs at Willings crossing, Winulta (H. Longbottom pers. comm.).

*Mid North* – Near Tarlee, escaping from a paddock, approximately 1 km from a 'Nationally Endangered' plant species (T. Reynolds pers. comm.). *T. ponticum* is widespread in the Northern Agricultural District (W. Avery pers. comm.), with dense infestations on roadsides in the Spalding and Jamestown districts (authors).

*Adelaide Hills* – Extending eastwards and upwards on the roadside from the Callington exit on South-Eastern Freeway (R. Taylor pers. comm., authors). Occurs on Flaxley Rd outside Mt. Barker on the roadside (A. Crompton pers. comm.).

*Adelaide* – Occurs on road verges near Lonsdale and footpath verges in Christies Beach (R. Taylor pers. comm.).

*Fleurieu* – *T. ponticum* is present on the shores of Lake Alexandrina near Milang (N. Mallen pers. comm., authors) and at Black Swamp, Currency Creek (R. Taylor pers. comm.).

*Kangaroo Island* – Occurs on roadside areas adjacent to plantings around salt patches (L. Dohle pers. comm., K. Moritz pers. comm.).

*Upper South-East* – *T. ponticum* is frequent adjacent to the Princes Highway between Taillem Bend and Millicent, with about 35 locations including extensive infestations of 1 km or greater at 10 locations (T. Reynolds pers. comm.). Plants almost always occur in low lying areas or natural wetlands. *T. ponticum* is present in the Coorong NP (a RAMSAR Wetland) in at least 10 locations. It is also present adjacent to the Dukes Highway, 30 km west of Kiki, and on the roadside between Keith and Naracoorte (authors).

*Lower South-East* – *T. ponticum* occurs on roadsides and flats between the Avenue Ranges, east of Lucindale, but it is not known in bushland (Z. Stokes pers. comm.).

Figure 24 shows recorded locations of *T. ponticum* naturalised in SA.

Within Australia. *T. ponticum* is listed as a weed in all southern states of Australia (Lazarides et al. 1997). In Victoria it has rapidly invaded upper saltmarsh at Lake Connewarre, near Geelong (McMahon et al. 1994b), and has also been observed invading a number of native grasslands in central, western and north-western Victoria (G. Carr and M. White pers. comm.).



Internationally. *T. ponticum* has been planted as a forage grass in western North America. It is naturalised in all western states of the USA (BONAP 2001). It is also naturalised in Buenos Aires province in Argentina (Borrajo 1997).

### **Establishment**

*T. ponticum* is large-seeded compared to other pasture grasses (Asay and Knowles 1985). However, seeds are still comparatively small at 190 000 seeds per kg (Oram 1990), equating to approx. 5 mg per seed. *T. ponticum* germinates well (Oram 1990) but can be slow to establish. In saline environments it has very poor early growth and young plants have a prostrate habit (Smith 1996). *T. ponticum* is a summer-active perennial with little growth in winter (Smith 1996), a trait that would slow establishment of autumn sowings. In high rainfall or summer moist sites it can be sown in spring (Bowyer 1998). In Utah, USA, *T. ponticum* does not establish where seedlings are subjected to dry conditions (Harrison et al. 1995). However, once established the species has a deep root system which enables it to access groundwater, and thereby survive droughts (Asay and Knowles 1985). *T. ponticum* prefers to establish in relatively open ground (A. Crompton pers. comm.) with reduced competition from other plants.

The native habitat of *T. ponticum* is saline meadows and seashores (Asay and Knowles 1985, citing Beetle 1955). In SA it has been observed establishing in natural samphire areas (including lake and river edges), waterways, and roadsides which often have high moisture levels (B. Bartel pers. comm., authors pers. obs.). It has also been observed sporadically on roadsides on upper slopes, which are presumably well-drained and without a high soil water table (authors). In SA *T. ponticum* has generally not been observed in relatively intact stands of dryland native vegetation such as mallee or woodland (A. Harvey pers. comm., J. Edwards pers. comm.), although it has been observed invading *Eucalyptus petiolaris* and *Eucalyptus odorata* woodlands downstream from plantings on lower Eyre Peninsula (L. Bebbington pers. comm.). In Victoria it has been observed invading native *Themeda triandra*, *Austrostipa* and *Austrodanthonia* grasslands.

To date, the main vegetation type invaded in southern Australia is dry saltmarsh, containing low native halophytes such as samphire (*Halosarcia* spp.) (G. Carr and M. White pers. comm.). There are concerns that coastal dunes may also become colonised (D. Symon pers. comm.).

### **Reproduction**

*T. ponticum* 'Tyrell' is cross-fertile and gives good seed yields (Oram 1990). Flowering stems are relatively unpalatable (Oram 1990), and also grow to above sheep grazing height. Thus seed production is not greatly impaired under light to moderate grazing. Seed production would be greater than 1000 seeds per m<sup>2</sup> per year for a group of plants. Weiss and Iaconis (2001) conservatively estimated approximately 1600 seeds per plant.

*T. ponticum* does not have rhizomes. No vegetative reproduction occurs.

### **Dispersal**

Long-distance seed dispersal of *T. ponticum* appears to be predominantly by water. New plants were often observed spreading along watercourses and drainage lines from planted stands. Some spread along roadsides is also likely by mowers.

## **IMPACTS**

### **Density**

Monocultures of *T. ponticum* have been observed on roadsides and adjacent to watercourses and swamps at various locations throughout southern SA. In the USA, in sites where *T. ponticum* roots can access a soil water table, it can establish as a dominant species and form a monoculture (Harrison et al. 1995). On drier soils it is more susceptible to competition from other grasses (Harrison et al. 1996). Thus for sites with high soil moisture availability and/or a shallow soil water table, *T. ponticum* has the potential to reach a **high** density.

### **Competitiveness**

Once established, *T. ponticum* is a competitive plant. The root system of *T. ponticum* can reach down to 3.5 m in wet saline soil (Robertson 1955 in Jarwal et al. 1996) with a large amount of the root system near the soil surface (Jarwal et al. 1996). Dense, tall tussocks over 1 m high can shade smaller plants. Monocultures of *T. ponticum* will exclude regeneration of most native plants, becoming a dominant biomass component of the vegetation. A major reduction in the diversity of groundcover flora would be expected. Removal of tall wheatgrass monocultures on lower Eyre Peninsula has led to rapid recolonisation of native species (L. Bebbington pers. comm.).

On drier soils *T. ponticum* may be less competitive against winter-growing grasses. In southwest Oregon, Borman et al. (1992) found that this species extracted soil water later in the growing season than some of the other pasture species tested, and suggested that this feature may make it less competitive with the resident annual species.

### **Movement**

The tall, perennial tussocks of *T. ponticum* hinder physical movement by vehicles, people and animals throughout the year. They may also cause silting of waterways.

### **Health risks**

There are no known health risks associated with *T. ponticum*.

### **Ecosystem health**

The accumulation of unpalatable, dense, tall foliage is likely to increase the likelihood of fire, particularly for saltmarsh communities.

## **POTENTIAL DISTRIBUTION**

### **Climate tolerances**

In North America *T. ponticum* grows best in rangeland areas receiving at least 350-400 mm of annual rainfall (Asay and Knowles 1985), but will also grow in drier areas with access to a shallow soil water table. Summer and autumn rainfall is important for productivity and persistence in low rainfall regions without a ground water table (Oram 1990).

A climate match (temperature and rainfall) for *T. ponticum* was done based on its distribution in Australia (state herbarium records, Smith 1996, Rogers and Bailey 1963), the USA (CalFlora 2001, Invaders 2001) and Turkey (GRIN 2001). This indicated that most of the southern agricultural zone of SA was climatically suitable for *T. ponticum*. However, it is likely that some sites used in the climate prediction had high water tables, so that the prediction may be overestimating dryland sites suitable for *T. ponticum*. Hence soil preferences were limited to sites with a high water table, to give a more conservative prediction of areas at risk of invasion. This may be too restrictive as occasional plants have been observed on upper slopes in SA (authors). However, *T. ponticum* may not perform well in drier sites in a Mediterranean climate due to poor seedling vigour and low winter growth rates (K. Smith pers. comm.).

### **Soil tolerances**

*T. ponticum* is well-adapted to poorly-drained and saline or alkaline soils (Oram 1990). Mature plants grow well on wet saline sites that dry out in summer (Jarwal 1996).

The PIRSA Land Information soil attribute and classes selected for *T. ponticum* were:

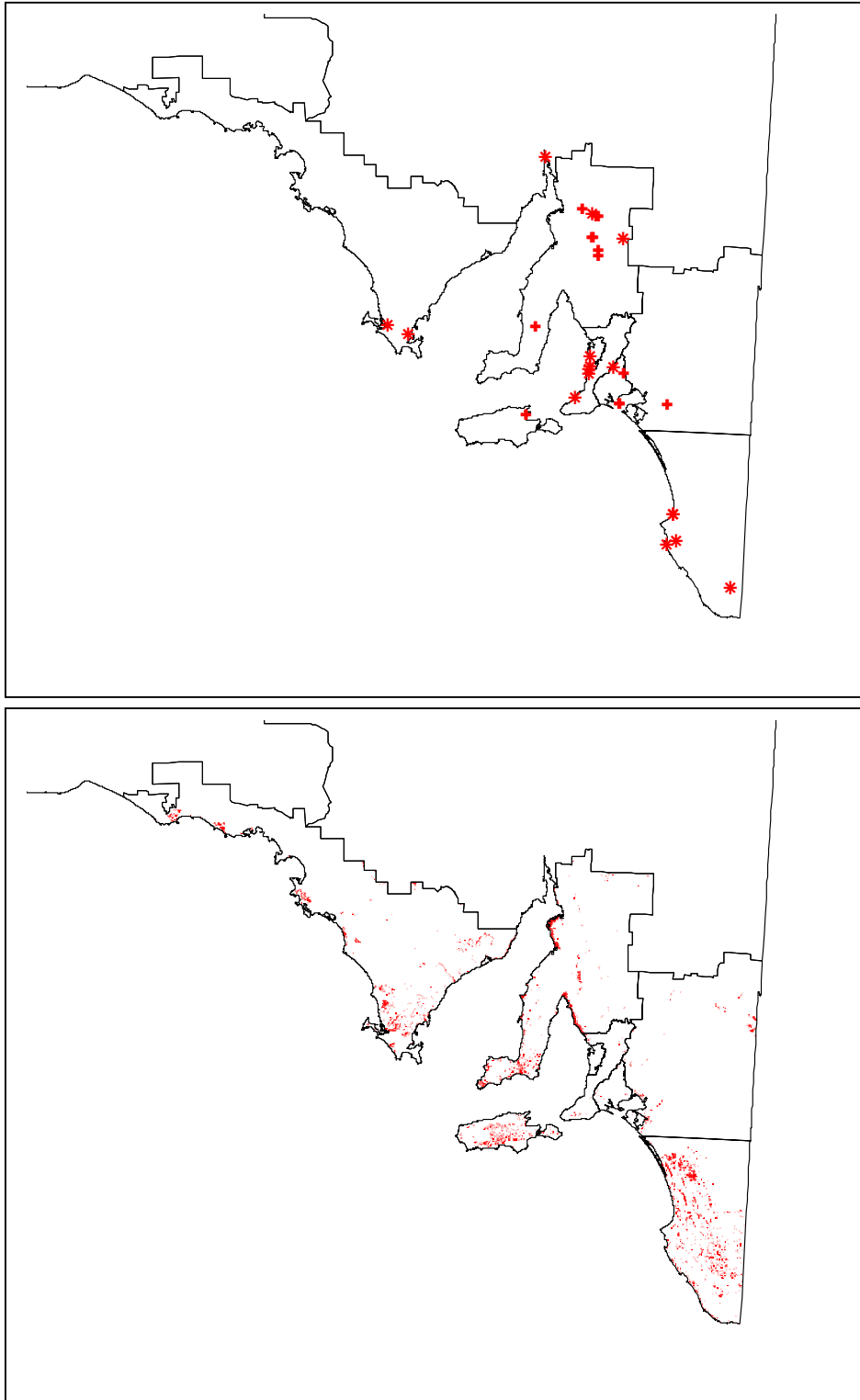
- Depth to Water Table – 200 cm to above surface for up to 3 months.

### **Areas at risk**

The areas and regional proportions of native vegetation in SA with potential for invasion by *T. ponticum* are shown in Figure 24 and Table 24 respectively.

**Table 24. Regional proportions of native vegetation with potential for invasion by *Thinopyrum ponticum*.**

Region	Proportion of native vegetation at risk
Eyre	4%
Northern Agricultural Districts	10%
Mt Lofty Ranges / Adelaide Metropolitan	4%
Kangaroo Island	8%
Murray Darling Basin	1%
South-East	25%
<i>Southern SA (all of above regions)</i>	6%
Rangeland / Aboriginal Lands	0%



**Figure 24. Known locations of naturalised *Thinyrium ponticum* (top) and areas of native vegetation with potential for invasion by the species in SA (bottom). Location symbols are: \* State Herbarium of SA records, + Authors records.**

## **Weed risk assessment scoring for grasses**

Figures 25 and 26 show the weed risk assessment scoring for the grass species across southern SA (all regions excluding Rangelands / Aboriginal Lands). Key criteria scores are summarised in Table 25. Table 26 lists regional Weed Importance scores.

In general terms across southern SA, *Ehrharta calycina* scored as high environmental weed risk (weed importance score between 84 and 209). *Thinopyrum ponticum* scored as a low environmental weed risk at this geographic scale (weed importance score between 3 and 29), putting it in the same risk category as the proclaimed plants pampas grass and African feathergrass. *Puccinellia ciliata* and *Themeda triandra* both scored as negligible weed risk across southern SA. In the latter's case this was because the species is indigenous across SA.

At the regional level, *E. calycina* was a high weed risk for all southern regions, and a medium weed risk for the Range/AL region. *Thinopyrum ponticum* scored as high weed risk in the SE, and a medium weed risk for the NAD and KI regions. It was a low weed risk for the Eyre, MLR/Metro and MDB regions due to a low proportion of remnant native vegetation overlying shallow soil water tables. With a Weed Importance score of 3, *P. ciliata* just reached the lower cut-off mark to be a low weed risk in the SE.

**WEEDS:**

<i>Ehrharta calycina</i>	<i>Puccinellia ciliata</i>	<i>Themeda triandra</i>	<i>Thinopyrum porticum</i>
Perennial Veldt Grass	Puccinellia	Kangaroo Grass	Tall Wheslgrass

**REGION:**  
Southern agricultural zone (NHT regions: Eyre, Northern Agricultural Districts, Mount Lofty Ranges, Metropolitan, Kangaroo Island, Murray-Darling Basin, South-East)

**LANDUSE:**  
Native Vegetation

Assumptions/Comments:  
On average across the state, there is no routine weed management. No stock grazing. No products leaving the landuse. Domestic animals are dogs and horseriding occasionally.

**A) INVASIVENESS**  
Answer all questions with the landuse in mind, except for question 5(a)

1. What is the weed's ability to establish amongst existing plants?  
3 = very high  
2 = high  
1 = medium  
0 = low  
? = don't know

2	0	1	1
---	---	---	---

2. What is the weed's tolerance to average weed management practices in the landuse?  
These practices (or lack thereof) can be listed in the above landuse assumptions.  
3 = very high  
2 = high  
1 = medium  
0 = low  
? = don't know

3	3	3	3
---	---	---	---

3. What is the reproductive ability of the weed:

(a) Time to seeding?  
2 = 1 year  
1 = 2-3 years  
0 = >3 years / never  
? = don't know

2	2	2	2
---	---	---	---

(b) Seed set?  
2 = high  
1 = low  
0 = none  
? = don't know

2	2	1	2
---	---	---	---

(c) Vegetative spread?  
2 = fast  
1 = slow  
0 = none  
? = don't know

1	0	0	0
---	---	---	---

**TOTAL:**  
**SCORE FOR 3:**  
3 = total of 5 or 6  
2 = total of 3 or 4  
1 = total of 1 or 2  
0 = total of 0

5	4	3	4
3	2	2	2

4. How likely is long-distance dispersal by natural means:

(a) Flying birds?  
2 = common

0	0	0	0
---	---	---	---

(b) Other wild animals?  
1 = occasional

2	?	0	0
---	---	---	---

(c) Water?  
0 = unlikely

1	2	0	2
---	---	---	---

(d) Wind?  
? = don't know

1	1	0	0
---	---	---	---

**TOTAL:**  
**SCORE FOR 4:**  
3 = total of 6 to 8  
2 = total of 3 to 5  
1 = total of 1 or 2  
0 = total of 0

4	3	0	2
2	2	0	1

5. How likely is long-distance dispersal by human means:

(a) Deliberate by people? (ignore landuse)  
2 = common

2	2	2	2
---	---	---	---

(b) Accidentally by people?  
1 = occasional

2	?	0	1
---	---	---	---

(c) Contaminated produce?  
0 = unlikely

0	0	0	0
---	---	---	---

(d) Domestic/farm animals?  
? = don't know

1	1	0	0
---	---	---	---

**TOTAL:**  
**SCORE FOR 5:**  
3 = total of 6 to 8  
2 = total of 3 to 5  
1 = total of 1 or 2  
0 = total of 0

5	3	2	3
2	2	1	2

**TOTAL INVASIVENESS SCORE:**

12	9	7	9
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Figure 25. Invasiveness scoring for the grass species using the Weed Importance Scoresheet.

		<i>Ehrharta calycina</i>	<i>Puccinellia ciliata</i>	<i>Themeda triandra</i>	<i>Thinopyrum ponticum</i>	
		Perennial Veldt Grass	Puccinellia	Kangaroo Grass	Tall Wheatgrass	
<b>WEEDS:</b>						
<b>B) IMPACTS</b>						
Assume the average weed management practices have not changed to specifically target the weed, and it has spread across/along a whole paddock, orchard, plantation, nature reserve or water body. If the weed is well-controlled by these average practices then it will occur at a low density and will have minimal impacts.						
<b>What density would the weed achieve?</b>		L = LOW M = MEDIUM H = HIGH	<b>H</b>	<b>L</b>	<b>M</b>	<b>H</b>
1. Does the weed reduce the establishment of desired plants?	3 = > 50% reduction 2 = 10-50% reduction 1 = < 10% reduction 0 = none ? = don't know		<b>3</b>	<b>1</b>	<b>1</b>	<b>3</b>
2. Does the weed reduce the mature yield or amount of desired vegetation?	4 = > 50% reduction 3 = 25-50% reduction 2 = 10-25% reduction 1 = < 10% reduction 0 = none ? = don't know		<b>2</b>	<b>0</b>	<b>1</b>	<b>3</b>
3. Does the weed reduce the quality of products or services obtained from the landuse?	3 = high 2 = medium 1 = low 0 = none ? = don't know		<b>2</b>	<b>0</b>	<b>0</b>	<b>2</b>
4. Does the weed restrict the physical movement of people, animals, vehicles and/or water?	3 = high 2 = medium 1 = low 0 = none ? = don't know		<b>0</b>	<b>0</b>	<b>0</b>	<b>2</b>
5. Does the weed affect the health of animals and/or people?	3 = high 2 = medium 1 = low 0 = none ? = don't know		<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>
6. Does the weed have major, positive or negative effects on environmental health:						
(a) food/shelter?			0	0	-1	0
(b) fire regime?	-1 = major positive effect		1	0	0	1
(c) increase nutrient levels?	1 = major negative effect		0	0	0	0
(d) soil salinity?	0 = minor or no effect		0	0	0	0
(e) soil stability?	? = don't know		0	0	0	0
(f) soil water table?			0	0	0	0
	<b>TOTAL:</b>		<b>1</b>	<b>0</b>	<b>-1</b>	<b>1</b>
	<b>SCORE FOR 6:</b>					
	3 = total of 4 to 6 2 = total of 2 or 3 1 = total of 1 0 = total of 0 or less		<b>1</b>	<b>0</b>	<b>0</b>	<b>1</b>
<b>TOTAL IMPACTS SCORE:</b>			<b>8</b>	<b>1</b>	<b>2</b>	<b>11</b>
<b>C) POTENTIAL DISTRIBUTION</b>						
In the Board, what area of the landuse is suitable for the weed?	10 = 95-100% of landuse, 9 = 85-95%, 8 = 75-85% 7 = 65-75%, 6 = 55-65% 5 = 45-55%, 4 = 35-45% 3 = 25-35%, 2 = 15-25% 1 = 7.5-15%, 0.5 = 1-7.5% 0 = <1%, ? = don't know		<b>5</b>	<b>0.5</b>	<b>0</b>	<b>0.5</b>
<b>WEED IMPORTANCE SCORE</b>						
Scores adjusted to range between 0 and 10						
<b>ADJUSTED INVASIVENESS SCORE:</b>			8.0	6.0	4.7	6.0
<b>ADJUSTED IMPACTS SCORE:</b>			4.2	0.5	1.1	5.8
<b>POTENTIAL DISTRIBUTION SCORE:</b>			5.0	0.5	0.0	0.5
<b>WEED IMPORTANCE =</b>			<b>168</b>	<b>2</b>	<b>0</b>	<b>17</b>
(Multiplying the scores)						
<b>Number of questions answered as "don't know"</b>			<b>0</b>	<b>2</b>	<b>0</b>	<b>0</b>

Figure 26. Impacts, Potential Distribution (for southern SA) and Weed Importance scoring for the grass species using the Weed Importance Scoresheet.



**Table 25. Summary of criterion and final scores for the shrub species for southern SA within the native vegetation landuse. Scoring for other environmental weeds which are proclaimed plants has been included for comparison (APCC data).**

Species	Invasiveness	Impacts	Potential Distribution	Weed Importance
<i>Ehrharta calycina</i>	8.0	4.2	5	168
<i>Puccinellia ciliata</i>	6.0	0.5	0.5	2
<i>Themeda triandra</i>	4.7	2.1	0	0
<i>Thinopyrum ponticum</i>	6.0	5.8	0.5	17
<b>Proclaimed:</b>				
<i>Cortaderia selloana</i> (Pampas grass)	6.7	5.3	0.5	18
<i>Eragrostis curvula</i> (African lovegrass)	5.3	1.1	5	29
<i>Nassella trichotoma</i> (Serrated tussock)	5.3	1.1	0.5	3
<i>Pennisetum macrourum</i> (African feathergrass)	6.0	4.5	0.5	14

**Table 26. Weed Importance scores for the shrub species for different regions.**

Species	Eyre	NAD	MLR/ Metro	KI	MDB	SE	Range /AL
<i>Ehrharta calycina</i>	202	101	134	101	202	202	67
<i>Puccinellia ciliata</i>	2	2	2	2	0	3	0
<i>Themeda triandra</i>	0	0	0	0	0	0	0
<i>Thinopyrum ponticum</i>	17	35	17	35	17	104	0

1. Regions are Eyre, Northern Agricultural Districts, Mt Lofty Ranges / Adelaide Metropolitan, Kangaroo Island, Murray Darling Basin, South-East and Rangeland / Aboriginal Lands.

## DISCUSSION

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### **Comparative Environmental Weed Risks of the Twenty Species**

A summary of the relative environmental weed risks of the twenty species on a regional basis is given in Table 27. There is no independent ranking of the weediness of the species with which to compare the validity of the results. However, the high to very high weed risks posed by some species has already been recognised in South Australia through initiation of large-scale control programs. *Pinus radiata* in native vegetation adjacent to plantations has been regularly controlled (prior to escaped trees setting seed) by ForestrySA in the South-East and Mt Lofty Ranges. Community action groups have been established on the lower Eyre and Yorke Peninsulas targeting *Pinus halepensis* infestations. *Acacia cyclops* control has been undertaken by the District Council of Yorke Peninsula. In addition, the species ranked as very high weed risk have also been frequently cited as major environmental weeds. Various *Ehrharta* species, including *Ehrharta calycina*, have been listed as serious bushland weeds in southern Australia in various reviews and guides (e.g., Humphries et al. 1991, Robertson 1994, Blood 2001, Muyt 2001). *Acacia saligna*, *Acacia cyclops*, *Pinus radiata* and *Pinus halepensis* are serious invaders in South Africa (see previous sections for references). Only *Pinus brutia* does not have a history of serious impacts as an environmental weed. However, it has not been in cultivation as frequently as other pines, and it has been flagged as a potential invader (Rejmanek and Richardson 1996).

*Eucalyptus cladocalyx*, *Casuarina glauca*, *Chamaecytisus palmensis* and *Thinopyrum ponticum* were ranked as medium to high weed risks in some regions. *Casuarina glauca* and *Thinopyrum ponticum* were assumed to be restricted in their potential distribution to sites with shallow soil water tables, but their capacity to form monocultures means they have potential for significant impacts on native vegetation at these sites. *Chamaecytisus palmensis* and *Eucalyptus cladocalyx* had somewhat lower Impacts scores, but their Potential Distribution scores for the MLR/Metro and SE regions raised their Weed Importance scores. The potential distribution of *Eucalyptus cladocalyx* may be too generous. Given its wide but scattered indigenous distribution in South Australia, some unidentified environmental factors may be significantly limiting its current distribution. The weed risk of *Chamaecytisus palmensis* needs to be kept in perspective to other weedy legumes. Gorse, Scotch broom and Cape broom had Impacts scores (and subsequently Weed Importance scores) 2.5 to 3 times higher than *Chamaecytisus palmensis* (see Table 19).

The *Eucalyptus* spp. (with the exception of *Eucalyptus cladocalyx*) had low to negligible weed scores, reflecting a poor establishment and dispersal ability, likely low to very low plant densities in native vegetation, and limited climate and soil suitability in areas of remaining native vegetation in SA. The *Atriplex* spp. were similarly thought to be limited in their invasiveness and impacts, and were unsuited to southern South Australia due to limited areas of clay soils and wetter climates. The low to negligible weed risk of *Medicago sativa* was expected as the species does not have a reputation as an environmental weed in Australia or overseas, despite being widely planted. *Puccinellia ciliata* was limited in its impacts and potential distribution, and hence scored as a mostly negligible weed risk.

**Table 27. Environmental weed risk categories for the twenty species in the seven regions. VH = very high, H = high, M = medium, L = low, N = negligible, I = indigenous**

Species	Eyre	NAD	MLR /Met.	KI	MDB	SE	Rng. /AL
<b>Trees:</b>							
<i>Casuarina glauca</i>	L	M	L	L	L	M	N
<i>Eucalyptus cladocalyx</i>	I	I	H	I	L	M	I
<i>Eucalyptus globulus</i> ssp. <i>globulus</i>	N	N	L	N	N	N	N
<i>Eucalyptus grandis</i>	N	N	N	N	N	N	N
<i>Eucalyptus occidentalis</i>	N	N	N	N	N	N	N
<i>Eucalyptus platypus</i>	N	N	N	N	N	N	N
<i>Eucalyptus saligna</i>	N	N	N	N	N	N	N
<i>Pinus brutia</i>	VH	H	VH	N	H	VH	L
<i>Pinus halepensis</i>	VH	VH	VH	H	H	VH	L
<i>Pinus radiata</i>	N	N	VH	H	L	VH	N
<b>Shrubs/Herbaceous perennials:</b>							
<i>Acacia cyclops</i>	I	M?	L	H?	VH	VH	N
<i>Acacia saligna</i>	H	H	VH	H	M	H	N
<i>Atriplex amnicola</i>	N	N	N	N	N	N	N
<i>Atriplex nummularia</i> ssp. <i>nummularia</i>	I	I	N	N	I	N	I
<i>Chamaecytisus palmensis</i>	N	N	H	L	L	L	N
<i>Medicago sativa</i> ssp. <i>sativa</i>	N	L	N	N	L	L	N
<b>Grasses:</b>							
<i>Ehrharta calycina</i>	H	H	H	H	H	H	M
<i>Puccinellia ciliata</i>	N	N	N	N	N	L	N
<i>Themeda triandra</i>	I	I	I	I	I	I	I
<i>Thinopyrum ponticum</i>	L	M	L	M	L	H	N

1. Regions are Eyre, Northern Agricultural Districts, Mt Lofty Ranges / Adelaide Metropolitan, Kangaroo Island, Murray Darling Basin, South-East and Rangeland / Aboriginal Lands.

In regions where *Eucalyptus cladocalyx*, *Acacia cyclops*, *Atriplex nummularia* and *Themeda triandra* were indigenous they were assumed to have a zero Potential

Distribution score, as the species could not be considered new weed invaders. This automatically gave them zero Weed Importance Scores.

### ***Limits of the Weed Risk Analysis***

Weed risk assessment is a tool which is used to make technically-based, objective and transparent decisions on relative weed threats. Decisions have to be made within the limits of currently available information. Often there is little quantitative data for plant species in relation to potential weediness, and available scientific knowledge, expert opinion and personal observations all need to be utilised in answering questions. Weed risk assessment systems also need to be flexible and evolving, with both the system and weed scores changing with improved knowledge.

The following limits of the current analysis need to be recognised:

- Scientific measurements were not specifically taken on the species during this project. Rather, existing literature and personal observations by revegetation, weed control and native vegetation management professionals were interpreted to answer the risk assessment questions.
- CLIMATE, the climate-matching model used as the first stage in predicting potential weed distribution, is limited to a 0.5 degree grid (approximately 50 x 50 km). This may unfairly average climates in areas of the state that have high variation in climate over a relatively short distance. For example, weeds suited only to the high rainfall areas in the central Mt Lofty Ranges may not be predicted.
- The native vegetation GIS data used did not have attributes relating to vegetation type, canopy cover, degree of past disturbance or conservation value (e.g., threatened species, reserve status). This resulted in two limits:
  - Vegetation characteristics will influence susceptibility to invasion by different weed species. For example, grasses generally do not grow well under shading and would be less invasive in forests than grasslands. Areas of native vegetation at risk are probably overestimated in the current analysis.
  - All areas (i.e. GIS polygons) of native vegetation were treated the same in the analysis, with no differences in conservation value. Thus a weed threatening a rare habitat or species was not given a higher weighting in comparison to a weed threatening more common habitats (see box below for more discussion).
- Fire will significantly enhance the seedling establishment of certain species considered in this report (e.g., the eucalypts, pines and acacias). However, fire has become a rare event for native vegetation due to fragmentation and active suppression of outbreaks. Thus the analysis assumed fire was rare, and species that spread rapidly and reach a high density without fire were a higher weed risk.
- Grazing will also effect the establishment and density of certain species considered in this report (e.g., *Themeda triandra*, *Ehrharta calycina* and *Chamaecytisus palmensis* are highly palatable). However, due to fragmentation of native vegetation, grazing pressure was considered to be low. This may have

overestimated the weed risk for regions where there is a high density of herbivores (e.g., Kangaroo Island).

- A species may have high Invasiveness and Potential Distribution scores and a relatively low Impacts score, yet still gets a medium Weed Importance score. It may be appropriate to determine a minimum Impacts score. However, the multiplication of the Invasiveness, Impacts and Potential Distribution scores is logical (explanation given in Appendix A).
- In calculating the Weed Importance scores for each region, the same Invasiveness and Impacts scores were used. This assumed similar behaviour of the species across their potential range. However, the considerable environmental variation within some of the SA regions needs to be recognised. For example, high average annual rainfall is limited to the southern tip of Eyre Peninsula, so species requiring such conditions will always have a low potential distribution for the Eyre region as a whole.
- The zero Potential Distribution score for regions where species are indigenous ignores the potential weed risks of introducing non-indigenous provenances of a species. However, natural competitors, pests and predators of the species are also likely to target the introduced provenance, limiting its weed potential. Another risk is the unknown future consequences of possible genetic crossing between indigenous and non-indigenous provenances. This was beyond the scope of the report.
- The potential risks of hybridisation between species was not assessed. The APCC system focuses on the potential weed behaviour of the species in question. Extension of the system to cover hybridisation risks would currently be too speculative, with more scientific studies needed on the likelihood and consequences of hybridisation.

### **Concerns with no weighting given to rare or threatened species and habitats**

Many submissions received on the draft report circulated for comment expressed concerns that there was no weighting given to areas containing rare or threatened species and habitats in determining the Potential Distribution score. A weed which threatens a rare natural habitat, such as swamps, will have a lower Weed Importance score than a weed which threatens a common natural habitat such as mallee. This is simply due to the latter having a higher Potential Distribution score for the proportion of areas of native vegetation at risk in SA.

*T. ponticum* was particularly highlighted in submissions as a species which is perceived to put at risk the population viability of rare or threatened species. For example, R. Davies (pers. comm.) listed seven threatened plant species from four rare plant communities across the state which would be susceptible to *T. ponticum* invasion.

The need to weight areas of native vegetation according to conservation value is acknowledged. However, this requires an agreed statewide process to determine relative conservation values, which would include consideration of reservation status, habitat and species diversity, area, vegetation condition and the presence of rare/threatened/endangered species and habitats. There are separate spatial datasets for South Australia titled "Rare and Endangered Plant Species", "Native Vegetation Heritage Agreements", "Wilderness Areas", "National Parks and Reserves" and "Vegetation – Remnant Native". These would need to be integrated in developing a spatial dataset with statewide coverage which includes an index of conservation value.

In the absence of an objective, widely-accepted and readily answerable criterion for relative conservation value of remnant native vegetation across South Australia, Potential Distribution scores have remained unweighted in this report.

## ***Managing Environmental Weed Risks***

### **RESPONSIBILITIES OF GROWERS**

This report has established that there are environmental weed risks associated with some species planted for forestry, revegetation and fodder in SA. Options to minimise the risks of such plant species spreading from plantings include:

- Not planting species of high to very high weed risk. This may be voluntary, or legally-enforceable under planning or noxious weeds legislation. For example, local governments in SA can assess the risk posed by a proposed new olive orchard to native vegetation and reject the development if the risk is deemed too high (APCC 1999). Non-native species can be prohibited for sale or movement under the Animal and Plant Control (Agricultural Protection and Other Purposes) [APC] Act, 1986. National initiatives such as the Garden Thugs list (Roush et al. 1999, Atkinson 2000) have sought to educate the garden industry and consumers about the environmental weed risks of certain ornamental species and foster the replacement of these with less invasive species.
- Surveillance and control of seedlings sourced from plantings. This again may be voluntary or legally-enforceable. For example, feral olives (*Olea europaea*) are proclaimed for mandatory control by landholders whom have the pest plant on their property, under the APC Act. Economic modelling by Harris et al. (2001) showed that there is significant net benefit in detecting and controlling even moderately invasive weeds early.
- Limiting seed production and viability. This could include genetic selection of cultivars with delayed time to seeding, greater resource allocation to vegetative rather than reproductive growth, reduced viable seed production and/or short seed longevity. However, selection for limited reproductive capacity would take substantial time. High-density plantings may reduce reproductive output (Jordon et al. 1999). Plantings of forage species could be kept at the browse height level of livestock, and mown or intensively grazed at specific times to limit seed production. Short rotation coppice species will have limited reproductive potential.
- Limiting seed dispersal. Seed dispersal declines rapidly with distance from a parent plant (Cousens and Mortimer 1995), so establishment of a buffer zone around a planting of a species (within which seedlings are controlled) is likely to significantly reduce the risk of spread. Bird dispersal is difficult to manage and high weed risk species which are commonly spread by birds are best not grown. However, the distance of seed dispersal by birds declines exponentially from the seed source, especially if there are nearby perching sites (as observed by Mladovan 1998 for olives). Species which have seed commonly spread by water can be planted distant from watercourses. Plantings of species which may have seed spread by livestock can be fenced off. Minimum planting distances from areas of significant native vegetation (including sites with nationally threatened plant species or ecological communities, conservation reserves, Ramsar or World Heritage sites) should be determined and adopted.
- Limiting vegetative spread. The use of non-suckering forms of species is preferred to reduce the risk of spread and provide for easier control.

- Limiting establishment ability. Species which have specific requirements for germination (e.g., cold requirements to break seed dormancy) and/or establishment (e.g., low seed reserves and a high seedling light requirement) which will not be readily met under the local environmental conditions and/or in native vegetation will present a lower weed risk. However, this may increase the financial cost of establishment and hence landholders may not adopt such species.

These options need to be tailored to develop risk management guidelines for growing high weed risk species.

## **RESPONSIBILITIES OF NATIVE VEGETATION MANAGERS**

In addition to minimising spread of high weed risk species from plantings, preventative and early intervention actions need to occur by managers of native vegetation to protect areas of high conservation value. This is particularly the case where a cultivated species is already widely naturalised in a region, so that plantings are not a major contributor to the spread of the species. In this instance it is better to focus on protecting sites of high conservation significance, through surveillance and control of major weed threats within and surrounding these sites.

The New Zealand Department of Conservation is a world leader in pro-active management of environmental weeds threatening conservation areas. The bulk of the Department's weed control work consists of "site-led" control programs, which are prioritised based on a ranking system for biodiversity value and urgency of control (Timmins and Owen 2001). This is supported by a weed surveillance plan integrating systematic and fortuitous searching to locate weeds when control costs are low (Braithwaite 2000, Harris et al. 2001). Weed management strategies for key conservation sites in SA need to be developed and implemented to avoid irreparable damage to biodiversity due to weed invasion.



## CONCLUSIONS & RECOMMENDATIONS

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For some forestry, revegetation and fodder plants used in SA there is a conflict of interest between the economic and/or environmental benefits obtained by cultivating the species, and the biodiversity loss and control costs where the same species spreads to become a significant weed of native vegetation. There are also some agricultural and forestry species grown which pose negligible weed risks to remnant native vegetation in SA. High and very high weed risk species should not be grown unless there is no practical alternative, or the species is already so widely naturalised in a region that cultivated plants are now a minor contributor to the weed's spread. In both cases appropriate weed risk management guidelines need to be developed and adopted.

Recommendations are given below on how to manage the weed risk of individual species. The utility/profitability of the species and the feasibility of controlling its spread are considered in conjunction with the weed risk in making the recommendations. General recommendations on improving environmental weed risk management in SA are also given below.

### **Trees**

#### **CASUARINA GLAUCA**

*Casuarina glauca* is a medium to low environmental weed risk at the regional scale, but poses a significant monoculture threat to native vegetation in riparian zones, swamps and other areas with a shallow water table across southern SA. In its favour it may have considerable potential as a 'pump' for saline groundwater in agricultural systems. Its vegetative spread makes it cost-effective in establishing dense salt scald and windbreak plantings. However, this vegetative spread makes it very difficult to eradicate once it is established in native vegetation (E. Robertson pers. comm.), and also causes problems in road maintenance. Fortunately it appears to have limited seedling establishment in SA, and plantings distant from native vegetation and waterways appear relatively safe provided vegetative spread is managed. The follow actions are recommended:

1. Ensure current revegetation advice on the species (including fact sheets) include warnings of environmental weed risk.
2. Develop and promote weed risk management guidelines for use of *C. glauca* in rural revegetation. This would include a wide buffer zone from native vegetation, roadsides and watercourses/swamps, and management of vegetative spread (e.g., routine livestock grazing or soil cultivation around plantings).
3. Make the community and garden/landscape industry aware of the environmental weed risk of *C. glauca*, and promote the alternative use of indigenous *Allocasuarina* species.
4. Ensure safe and effective control techniques for *C. glauca* infestations are available to native vegetation managers, including herbicide registrations.
5. Develop and implement local weed management strategies to control existing infestations which are threatening significant areas of riparian native vegetation in SA.

## **EUCALYPTUS CLADOCALYX**

*Eucalyptus cladocalyx* is a high environmental weed risk in the MLR and a medium environmental weed risk in the SE. Its potential distribution in SA may have been overestimated. However, it has spread from plantings in these regions, interstate and overseas. The SA origins of *E. cladocalyx* and its performance relative to other eucalypts in drier areas make it a popular species for planting, particularly for woodlots. Seedlings are relatively easy to control, but (for the untrained eye) are not readily distinguishable from other indigenous eucalypts. Rate of spread is relatively slow and there is no soil seedbank, so local control programs are likely to be successful. Planting the Northern Mt Lofty Ranges/Flinders Ranges genotypes adjacent to natural populations on lower Eyre Peninsula or Kangaroo Island poses a risk of genetic mixing. The following actions are recommended:

1. Ensure current revegetation advice on the species (including fact sheets) include warnings of environmental weed risk (in relevant regions) and information on how to control seedlings.
2. Develop and promote weed risk management guidelines for *E. cladocalyx* in the MLR and SE.
3. Develop and implement local weed management strategies to control existing infestations which are threatening significant areas of native vegetation in the MLR and SE.
4. Investigate the risks and consequences of genetic crossing between a planted, non-indigenous provenance and an indigenous *E. cladocalyx* population. Develop guidelines on safe planting distances for such situations.

## **EUCALYPTUS GLOBULUS, E. GRANDIS, E. SALIGNA, E. OCCIDENTALIS AND E. PLATYPUS**

These species all pose low to negligible environmental weed risk. Control of seedling eucalypts is relatively easy and there is no persistent soil seedbank. Monitoring for seedlings would be particularly needed in the year following a fire. These species do not need specific weed risk management guidelines. However, the following precautionary action is suggested:

1. Any seedlings found spreading from non-indigenous eucalypt plantings into native vegetation should be controlled.
2. Frequent naturalisation of any *Eucalyptus* species should be investigated for potential future environmental weed risk.

## **PINUS BRUTIA**

*Pinus brutia* is a high to very high environmental weed risk in all southern regions, with the exception of KI for which it did not have a strong climate match. However, *P. brutia* may have significant economic potential as a straight-stemmed forestry tree in drier areas than where *Pinus radiata* is currently grown. *P. brutia* is similar to *Pinus halepensis* which is already a significant environmental weed in SA. *P. brutia* has later reproductive maturity and lower cone yields than *P. halepensis*, so it should be easier to contain in plantations.

Control of young pine infestations is relatively easy. Seedlings and juveniles of pines can be hand-pulled or cut at ground level. Long-distance seed dispersal is limited and there is no long-lived soil seedbank. Control programs can be at intervals of 5+ years before seed production occurs. *P. brutia* is relatively new to cultivation and is not known to be naturalised in SA. Its future commercial production in SA must include weed risk management practices to prevent a similar scenario to the current weed problems posed by *P. halepensis*. The following actions are recommended:

1. Ensure current revegetation advice on the species (including fact sheets) include warnings of environmental weed risk and information on how to control seedlings.
2. Ensure that cultivar development of *P. brutia* for southern Australia includes selection for reduced reproductive ability. Provenances with delayed reproduction and lower cone yields than *P. halepensis* occur (Panetsos 1981).
3. Develop mandatory weed risk management guidelines for *P. brutia* for use in conjunction with its promotion and development as a commercial forestry industry.
4. Limit *P. brutia* to forestry uses only to minimise infestations arising from uses such as windbreaks and amenity plantings. Ensure community awareness of the environmental weed risk of *P. brutia*.
5. Proclaim feral *P. brutia* plants for control throughout SA under the Animal and Plant Control (Agricultural Protection and Other Purposes) [APC] Act, 1986. A similar proclamation currently applies to feral olives.
6. Monitor *P. brutia* trials/plantings for occurrence of volunteer seedlings to seek confirmation of the weed risk prediction and the need for continued proclamation (if introduced).

## **PINUS HALEPENSIS**

*Pinus halepensis* is a high to very high environmental weed risk in all southern regions. It is not widely used as a timber or firewood tree, and there are alternative windbreak species. Control of seedlings/juveniles is relatively easy (see *P. brutia* above), although *P. halepensis* commences seeding earlier than *P. radiata* or *P. brutia*, so control programs need to be more frequent. Large trees are expensive to remove. Scattered infestations of *P. halepensis* occur across southern SA. Many are small and could be easily eradicated. Feral *P. halepensis* is currently a proclaimed plant requiring control in two Animal & Plant Control Boards (Southern Eyre and Mitcham). The following actions are recommended:

1. Ensure current revegetation advice on the species (including fact sheets) include warnings of environmental weed risk and information on how to control seedlings.
2. Proclaim feral *P. halepensis* plants for control throughout SA under the APC Act.
3. Make the community and garden/landscape industry aware of the environmental weed risk of *P. halepensis*, and promote low-weed risk alternatives.
4. Pending consultation on the current and future utility of the species and low weed risk alternatives, proclaim *P. halepensis* for sale and movement under the APC Act. This would limit new infestations.
5. Develop and implement local weed management strategies to control existing infestations which are threatening significant areas of native vegetation. Undertake

staged removal in combination with establishment of indigenous banksias, hakeas, and allocasuarinas in locations where black cockatoos are highly dependent on pine seeds (Threatened Species Network guidelines, V.J. Russell pers. comm.).

## **PINUS RADIATA**

*Pinus radiata* is a high to very high environmental weed in the MLR, SE and KI regions. However, it is also a very important industry for the South Australian economy. *P. radiata* seedlings and juveniles are relatively easy to control and spread is relatively slow. ForestrySA has been controlling feral pines in its native forest reserves for many years, at intervals of 5+ years, and deserves credit for this environmental responsibility. Infestations of *P. radiata* are relatively limited in extent compared to such weeds as olives or brooms. The following actions are recommended:

1. Ensure current revegetation advice on the species (including fact sheets) include warnings of environmental weed risk and information on how to control seedlings.
2. Plantation managers (government and private) undertake routine control of any pine seedlings spreading into native vegetation.
3. Develop weed risk management guidelines for *Pinus radiata* for use by the industry, including minimum planting distances from areas of significant native vegetation. Include weed risk management of forestry species in the Australian Forestry Standard.
4. Proclaim feral *P. radiata* plants for control throughout SA under the APC Act, with a strategic focus on protecting areas of native vegetation.
5. Make the community and garden/landscape industry aware of the environmental weed risk of *P. radiata*, as a disincentive to its use as a windbreak or ornamental in areas in close proximity to native vegetation.
6. Develop and implement local weed management strategies to control existing infestations which are threatening significant areas of native vegetation in the MLR, SE and KI regions.

## **Shrubs**

### **ACACIA CYCLOPS**

*Acacia cyclops* is a very high environmental weed risk in the MDB and SE regions. It may also pose a significant weed risk to the NAD and KI regions, if it is found to be non-indigenous there. A range of locally indigenous species could probably perform a similar soil stabilisation or windbreak function as *A. cyclops*. Control is moderately difficult. Shrubs do not re-sprout if cut, hence no herbicide is necessary for weed control (R. Taylor pers. comm.). However, a small proportion of the seed bank is long-lived in the soil so control programs will require follow-up measures. The seedlings are difficult to differentiate from locally native species when doing control work (R. Taylor, A. Allanson pers. comm.). Bird dispersal is frequent and difficult to manage. There is contention over whether *Acacia cyclops* is indigenous east of the western Eyre Peninsula. There are widely distributed, but as yet mostly relatively small, populations in central and eastern South Australia. The following actions are recommended:

1. Ensure current revegetation advice on the species (including fact sheets) include warnings of environmental weed risk (in relevant regions) and information on how to control seedlings.
2. Undertake genetic research into the distribution of *Acacia cyclops* in SA to determine where it is indigenous.
3. Discourage use *A. cyclops* for revegetation in eastern SA (MLR, MDB, SE regions) and the NAD and KI regions if the species is found to be non-indigenous there. Make the community aware of the environmental weed risk of *A. cyclops*, and promote indigenous alternatives.
4. Develop and implement regional weed management strategies where the species is found to be non-indigenous.

### **ACACIA SALIGNA**

*Acacia saligna* is a high to very high environmental weed risk across most of southern SA. Its quick growth and native appearance has made it a favoured species for direct seeding. It has had questionable utility as a fodder tree, rapidly growing above stock browse height and having poor digestibility due to high tannin content (Degen et al. 1997). However, it remains a favoured species for continued development for large-scale agroforestry (M. Ellis pers. comm.). Established infestations of *Acacia saligna* are difficult to control. Seedlings are hard to differentiate with locally native species and can't be confidently removed until mature foliage is present. (R. Chapman, A. Allanson pers. comm.). Trees readily sucker and cut stumps must be treated with herbicides. Repeated applications of herbicides may be needed. The long-lived soil seedbank means that control sites will need on-going monitoring. The familiar wattle appearance of *Acacia saligna* also makes it difficult to quickly locate new infestations, and to educate people that it is not an indigenous species in SA bushland. *Acacia saligna* has been widely used in ornamental landscaping and rural revegetation in southern SA, and is frequently naturalised in small infestations. It cannot be made a proclaimed plant under the APC Act as this specifically excludes "native plants" as defined in the National Parks and Wildlife Act, 1972. In this latter Act native plants are defined as "any plant that is indigenous to Australia and includes any plant of a species declared by regulation to be a native plant". The following actions are recommended:

1. Ensure current revegetation advice on the species (including fact sheets) include warnings of environmental weed risk, information on how to control seedlings, and the limited utility of *Acacia saligna* as a fodder tree at present.
2. Discourage the use of *A. saligna* for revegetation and landscaping, especially in direct-seeding mixes. Make the community and garden/landscape industry aware of the environmental weed risk of *A. saligna*.
3. Any cultivar development of *Acacia saligna* for southern Australia should include a major focus on reduced reproductive ability (e.g., low seed production, delayed time to seeding, low hard-seededness, reduced suckering capacity). Any subsequent promotion of large-scale agroforestry plantations should include weed risk management guidelines.
4. Develop and promote safe and effective control techniques for *Acacia saligna* infestations in native vegetation, including herbicide registrations.

5. Develop and implement local weed management strategies to control existing infestations which are threatening significant areas of native vegetation.

### **ATRIPLEX AMNICOLA AND A. NUMMULARIA**

These species pose negligible environmental weed risk and no risk management guidelines are warranted. As a precautionary action *A. amnicola* could be established with male clones only to prevent any seedset.

### **CHAMAECYTISUS PALMENSIS**

*Chamaecytisus palmensis* is a high weed risk in the MLR, due to a high proportion of native vegetation with suitable climatic and soil conditions. It is a low to negligible weed risk elsewhere in SA. It is often naturalised on roadsides adjacent to plantings in the MLR, but it has not spread or impacted in native vegetation to the same extent as brooms and gorse. *C. palmensis* is a productive fodder shrub with a role in lowering soil water tables, and is widely planted across southern SA. Infestations are quite feasible to manage, with low plant densities and control of established plants with the standard 'cut and paint' herbicide technique (Muyt 2001). However, follow-up control of seedlings emerging from the long-lived seedbank is needed. The following actions are recommended:

1. Ensure current revegetation advice on the species (including fact sheets) include warnings of environmental weed risk in high rainfall areas, and information on how to control seedlings.
2. Develop weed risk management guidelines for fodder plantings of *C. palmensis*. This would include a minimum planting distance from native vegetation, roadsides and watercourses, and pruning/grazing management to favour vegetative growth accessible to livestock.
3. Develop and implement local weed management strategies in the MLR to control existing infestations which are within significant areas of native vegetation.

### **MEDICAGO SATIVA**

*Medicago sativa* poses a low to negligible environmental weed risk and no risk management is required.

## **Grasses**

### **EHRHARTA CALYCINA**

*Ehrharta calycina* is a high environmental weed risk across southern SA, and a medium weed risk in the southern Range/AL region. However, it is also an important pasture species for low rainfall, sandy soil areas, and has high palatability. Complete control is difficult in native vegetation due to high plant densities, off-target damage from non-selective herbicides, ease of accidental seed spread and the need to locate isolated infestations. Fusilade<sup>®</sup>, a post-emergence, grass-selective herbicide is registered for *E. calycina* in native woodland in Western Australia but not SA. Repeated defoliation is

reputedly an effective means of control (P. Tucker pers. comm.). However, it is laborious and slashing at flowering/seeding can promote repeat flowering (K. Mercer pers. comm.). *E. calycina* has been widely planted across the state, such that regional control programs would have limited feasibility. It is eaten by kangaroos and probably other native herbivores, which may reduce its potential impact in rangeland areas and large reserves. The following actions are recommended:

1. Ensure current revegetation advice on the species (including fact sheets) include warnings of environmental weed risk.
2. Limit the use of *E. calycina* to pasture production in the southern agricultural zone of SA only, where its frequent grazing will limit seed production and dispersal. Discourage its use for soil stabilisation, where it may remain ungrazed (e.g., fenced dunes, roadsides, coastal areas) and spread to nearby native vegetation.
3. Develop and promote safe and effective control techniques for *E. calycina* infestations within native vegetation.
4. Identify significant areas of native vegetation which are currently free of *E. calycina* and develop and implement containment and early eradication strategies to protect these areas.

### **PUCGINELLIA CILIATA**

*Puccinellia ciliata* poses a mostly negligible environmental weed risk and no risk management is required.

### **THEMEDA TRIANDRA**

Due to its indigenous status *Themeda triandra* poses no environmental weed risk. However, revegetation with the species should use locally-sourced seed to maintain the genetic integrity of regional populations.

### **THINOPYRUM PONTICUM**

*Thinopyrum ponticum* is a high environmental weed risk for the SE and a medium risk for the KI and NAD regions. It is a high impact weed, but the assumption that its potential distribution will be limited to habitats with shallow soil water tables reduced its overall weed risk. There is some evidence of *T. ponticum* persisting in drier sites (e.g., in native grasslands in Victoria) and thus the area of native vegetation at risk in SA may be greater than predicted. Natural resource managers are becoming increasingly concerned about the environmental weed risk of *T. ponticum* (Elias 2002). In its favour, *T. ponticum* can perform a useful agronomic role as a summer-active, pasture grass that can tolerate wet, saline and/or alkaline sites. However, the main cultivar used to date, 'Tyrell', has poor palatability and requires frequent grazing or slashing to prevent it becoming rank and unproductive. The new cultivar 'Dundas' has greater palatability, which may reduce seed production and hence risk of spread. *T. ponticum* has been widely planted in saline areas across the state, but the total area of infestations on roadsides, watercourses and in native vegetation is still relatively small. Regional control programs would be constrained by its current agricultural use, and difficulties in identifying non-flowering plants. The following actions are recommended:

1. Ensure current revegetation advice on the species (including fact sheets) include warnings of environmental weed risk.
2. Limit the use of *T. ponticum* to pasture production only. Ungrazed areas of *T. ponticum* planted in saline areas pose a higher risk of seed production and spread beyond plantings.
3. Phase out the cultivar 'Tyrell'.
4. Develop weed risk management guidelines for *T. ponticum*. This would include a minimum planting distance from native vegetation, roadsides and watercourses/swamps, grazing management to maintain vegetative growth and minimise seed production, and control of plants spreading from plantings, and along watercourses and roadsides.
5. Develop and promote safe and effective control techniques for *T. ponticum* infestations within native vegetation, including herbicide registrations.
6. Identify significant areas of wetland native vegetation which are currently free of *T. ponticum* and develop and implement containment and early eradication strategies to protect these areas.
7. Study the soil moisture tolerances of *T. ponticum* to determine whether it poses a threat to native vegetation in SA beyond riparian and wetland situations.

### **General recommendations**

The following general actions are suggested to improve environmental weed risk management in SA in the longer term:

1. Plant developers consider low weed risk as a core requirement in selecting species/cultivars for future use in agriculture, forestry, horticulture, revegetation and landscaping in SA.
2. Develop a general framework for resolving conflicts of interest regarding new economic plants for primary industries which also pose significant environmental weed risks.
3. Develop a widely-accepted means of ranking conservation value of native vegetation areas in SA. This will greatly assist in determining priorities for prevention and early intervention actions against environmental weeds, as well as directing placement of high weed risk species away from significant native vegetation areas.
4. Consideration be given to the "polluter-pays" principle for certain economic species of high weed risk, in reviewing noxious weeds legislation in SA. Concerns were frequently expressed in this project by native vegetation managers of the cost imposed on them by control of species which had spread from adjacent plantings. Noxious weed legislation under the APC Act is currently limited in that proclaimed plants spreading to a neighbouring property become the recipient's legal (and financial) responsibility for control.
5. Change the definition of "native plant" in the APC Act to restricted it to species which are indigenous to SA only. *Acacia saligna* is an example of an Australian plant (from Western Australia) which poses a high weed risk in SA, yet it is cannot be proclaimed under any of the measures in the APC Act.



6. Consideration be given to mandatory notification of the high weed risk of some cultivated species, to ensure consumers are adequately informed before purchase.
7. Review the Significant Trees regulation in the Development Regulations 1993, so that non-proclaimed species which are known environmental weeds, and which are providing seed sources for further spread can be removed without legal hindrance.

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*Geoffrey Bishop	Dave Hein	*Vanessa Narbeth
*Monique Blason	Keith Hodder	*Michael Norris
*Jeff Bollard	*Iggy Honan	*Bob Osborne
John Bourne	*Melissa Horgan	*Bev Overton
*Wayne Brown	*David Hughes	Dennis Page
*Peter Bulman	Ryan Incoll	Angela Paltridge
Peter Butler	*John Jessop	Dennis Pfeiffer
*Pat Clark	*Manfred Jusaitis	Cathy Potts
*Geoff Carr	*Alex Knight	*David Powell
*Carlsa Carter	*Emil Kolak	*Ann Prescott
*Rosemary Chapman	Anton Kurray	*Tim Reynolds
Steve Clarke	*Helen Lamont	Helen Richards
Phil Collins	*Malcolm Lane	*Enid Robertson
David Cooke	Ann Lecher	*Alan Robins
*Geoff Cotton	*Vicki Linton	*Vicki-Jo Russell
*Don Cranwell	*Hugh Longbottom	*John Samuel-White
*Andrew Crompton	Phil McNamara	Richard Sage
*Rick Davies	*Anthony Maguire	*John Scarvelis

\*Peter Sheridan  
\*Kevin Smith  
\*Helen Smyth  
Rick Southgate  
\*Zita Stokes  
Robin Storr  
\*David Symon

\*Ron Taylor  
David Tonkin  
Detlev Vogt  
\*Peter Tucker  
\*Matthew Turner  
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Melanie Waters  
John Weiss  
\*Matt White  
Peter Willmott  
\*John Wills  
Jacqui Wilson  
\*Trevor Wynnias

## GLOSSARY

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### Abbreviations Commonly Used Within Text

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<b>Abbreviation</b>	<b>Name</b>
APCC	= Animal and Plant Control Commission
APC Act	= Animal and Plant Control (Agricultural Protection and Other Purposes) Act, 1986.
ATSC	= Australian Tree Seed Centre
AVH	= Australia's Virtual Herbarium
CP	= Conservation Park
CSIRO	= Commonwealth Scientific and Industrial Research Organisation
Eyre	= Eyre Peninsula NHT region
GIS	= Geographic Information System
KI	= Kangaroo Island NHT region
MDB	= Murray Darling Basin NHT region
MLR/Metro	= Mt Lofty Ranges / Adelaide Metropolitan combined NHT regions
NAD	= Northern Agricultural Districts NHT region (including Yorke Peninsula)
NHT	= Natural Heritage Trust
NP	= National Park
NPWS	= National Parks & Wildlife Service
NSW	= New South Wales
PIRSA	= Primary Industries & Resources South Australia
Range/AL	= Rangeland / Aboriginal Lands combined NHT regions
RP	= Recreation Park
SA	= South Australia
SE	= South East NHT region
WA	= Western Australia
WRA	= weed risk assessment

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## APPENDIX A

# WEED ASSESSMENT GUIDE – August 2002

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## INTRODUCTION

This guide for the Weed Assessment Scoresheet has been developed by the Animal and Plant Control Commission in cooperation with Animal and Plant Control Boards, to help in prioritising weeds for control programs. A series of questions are answered to compare the relative importance of different weeds. The questions are divided into three main criteria; invasiveness, impacts and potential distribution. **Invasiveness** looks at the weed's rate of spread, faster spreading weeds being a higher priority for control. **Impacts** are the economic, environmental and social effects the weed has. **Potential distribution** indicates what total area the weed could spread to. Scores for each of these criteria are multiplied (each ranging between 0 and 10), to give a weed importance score out of 1000. Weeds are assessed separately for various **landuses**, so that the most important weeds of different landuses can be identified.

**Note that the importance of a weed is a separate issue to its feasibility of control. Both need to be considered in setting Board weed priorities.** A scoring system for feasibility of control is yet to be developed. Key factors would include:

- How widespread the weed is. It's much more feasible to tackle recent arrivals rather than weeds which are entrenched across the majority of properties.
- Ease of finding infestations. A weed that is difficult to find due to small size, or difficult to distinguish from other weeds or native plants is much less likely to be successfully contained by landholders than larger weeds of novel appearance.
- Availability of cost-effective control techniques. This includes the range of physical, chemical and biological techniques available, and the costs of materials and labour. Broad acre farming has more scope than native vegetation for cost-effective control.
- Difficulty of limiting spread. Noxious weed laws do not work well for weeds which spread predominantly by natural means such as birds or wind.
- Seedbank Persistence. Long-lived seeds in soil extends the time needed for effective local eradication.
- Use of the plant. If the weed is also a horticultural crop, pasture grass or popular garden plant then it will continue to be planted and potentially start new infestations.

The suggested course of action is to decide on the most important weeds, and then develop management plans for these.

Use this guide when filling out the accompanying scoresheet. The questions can apply to any type of weed in any landuse. There may be **questions where you don't know the answer** for a certain weed, especially if it is not present in your area. In such cases choose the "don't know" option, and seek opinions from others (e.g. landholders, advisers, other Boards, researchers). "Don't know" is treated as a "0" in the spreadsheet. This avoids bias against weeds which have a score for all questions. However, weeds which have one or more questions answered as "don't know" are indicated as such at their final score. Sharing information and scores is the key to building up knowledge and getting the most out of the Weed Assessment System. Answering questions as a group is better than individually. It's particularly important to get consensus on assumptions about typical weed control in the landuse.

This scoring system is a tool to help in making standard, informed decisions on weed control priorities. Comments on the system are welcome for future improvements in its accuracy and ease of use.

## LANDUSES

Different types of weeds are important in different landuses. For example, annual weeds are problems in grain crops, and woody weeds are problems in native vegetation. If you were to compare the importance of weeds of different landuses, then you would also need to compare the importance of the landuses themselves. This is too difficult to do (i.e. you need \$/ha values for each landuse). An easier approach is to compare weeds within landuses only. Animal and Plant Control Boards can then decide for themselves the amount of time devoted to protecting each landuse.

The following landuses are suggested:

1. **Aquatic** (Permanent water bodies. e.g. rivers, swamps, canals, lakes, estuaries)
2. **Crop/Pasture rotation** (e.g. dryland cereals, pulses, oilseeds, legume pastures, hay)
3. **Forestry** (e.g. pines, blue gums)
4. **Irrigated crops and pastures** (e.g. vegetables, lucerne. Prone to summer weeds.)
5. **Native vegetation** (For nature conservation purposes. Public and private reserves.)
6. **Non-arable grazing** (Includes permanent pastures and rangelands.)
7. **Perennial horticulture** (e.g. vineyards, citrus, stone fruits)
8. **Urban** (e.g. sports fields, parks, footpaths)

Within each Board, landuses will vary in terms of what is grown and how crops/pastures/vegetation are managed. However, to keep the scoring system relatively simple and to answer at a Board or regional level, it is necessary to **think in averages**. There are two main aspects to keep in mind:

- (i) **Where a weed is only prevalent at certain phases in a landuse.** For example, the typical *crop/pasture rotation* landuse in a Board may have cereals, canola, pulses and pasture phases. In answering questions, average the *invasiveness* and *impacts* of a weed amongst these four vegetation types. Thus a weed which is only a problem in cereals will score less than a similar weed which is a problem in all crops and pasture. In the *potential distribution* section these two weeds will get the same score, as they will occupy the same area.
- (ii) **Where a weed only occurs in certain parts of a landuse.** For example, the *perennial horticulture* landuse in a Board may contain citrus, stone fruit, olives and vines. For a weed which only occurs in citrus and vines, average the *invasiveness* and *impacts* of a weed amongst these two vegetation types only. Then in the *potential distribution* section, the weed's score may be reduced because it is not a problem in all perennial horticulture crops in the Board area.

**Decide which landuses apply to your Board. Then decide which weeds cause problems in which landuses. There is no need (and it makes little sense) to assess every weed in every landuse. The idea is simply to determine the important weeds of each landuse.**

**Assumptions about a landuse can be recorded on the scoresheets.**

## INVASIVENESS

This section indicates how fast the weed can spread within a particular landuse. It takes account of how well the weed can establish, reproduce and disperse. Answer all questions with the landuse in mind, except for question 5(a).

1. What is the weed's ability to establish amongst existing plants?		SCORE
<input type="checkbox"/> very high	"Seedlings" readily establish within dense vegetation, or amongst thick infestations of other weeds.	3
<input type="checkbox"/> high	"Seedlings" readily establish within more open vegetation, or amongst average infestations of other weeds.	2
<input type="checkbox"/> medium	"Seedlings" mainly establish when there has been moderate disturbance to existing vegetation, which substantially reduces competition. This could include intensive grazing, mowing, raking, clearing of trees, temporary floods or summer droughts.	1
<input type="checkbox"/> low	"Seedlings" mainly need bare ground to establish, including removal of stubble/leaf litter. This will occur after major disturbances such as cultivation, overgrazing, hot fires, grading, long-term floods or long droughts.	0
<input type="checkbox"/> don't know		?

*Ignore any weed control practices for this question. Depending on the landuse, "vegetation" may be crops, pastures, lawns and/or native vegetation. Weeds that invade well-managed landuses (where a dense vegetative cover over soil is maintained) are assumed to be more important. High scoring weeds would include wild radish, bridal creeper and dodder.*

*Assume the plant has just arrived. "Seedlings" includes growth from dispersed vegetative propagules (e.g. broken fragments of couchgrass stems or silverleaf nightshade roots) and spores, in addition to seeds. "Seedlings" does not include new vegetative growth whilst still attached to the parent plant (e.g. by stolons, rhizomes or lateral roots). This feature is accounted for in question 3(c).*

*Features which can help a weed establish amongst existing plants include:*

- the ability to germinate under the canopy of other plants (e.g. weeds that have staggered germination in crops)*
- large seeds or vegetative propagules (e.g. bulbs, root fragments, tubers) provide more reserves to help the weed establish in competition with other plants*
- the ability to tolerate or avoid competitive stresses (e.g. by rapid root growth, fixing own nitrogen, or rapid vertical shoot growth)*

2. What is the weed's tolerance to average weed management practices in the landuse?		SCORE
<input type="checkbox"/> very high	Over 95% of weeds survive commonly used weed management practices.	3
<input type="checkbox"/> high	More than 50% of weeds survive.	2
<input type="checkbox"/> medium	Less than 50% of weeds survive.	1
<input type="checkbox"/> low	Less than 5% of weeds survive.	0
<input type="checkbox"/> don't know		?

Assume the weed is new to an area. This question looks at whether the new weed is killed by the weed management practices which are commonly used across the landuse. If most are killed then there will be few plants to reproduce and spread. If few are killed then changes to weed management practices will eventually be needed. Weed management practices include herbicides, cultivation, cutting/slashing, grazing, and fire. The types and timing of these practices may vary within landuses (e.g. for cereals and broadleaf crops, or vineyards and citrus), but average these. If a weed grows and seeds when there is normally no weed management (e.g. summer) then it is highly tolerant of the common weed management practices. Weeds with high tolerance to routine weed management would include silverleaf nightshade (difficult to kill), caltrop (quick to seed), and broomrape. In native vegetation there may be no commonly used weed management practices at a regional level - if so then include this in your assumptions about the landuse.

2. What is the reproductive ability of the weed in the landuse?				Total (a+b+c)	SCORE
<b>(a) Time to seeding</b>	<b>(b) Seed set</b>	<b>(c) Vegetative reproduction</b>	<input type="checkbox"/> high	5 or 6	3
<input type="checkbox"/> 1 year      2	<input type="checkbox"/> high      2	<input type="checkbox"/> fast      2	<input type="checkbox"/> medium-high	3 or 4	2
<input type="checkbox"/> 2-3 yrs      1	<input type="checkbox"/> low      1	<input type="checkbox"/> slow      1	<input type="checkbox"/> medium-low	1 or 2	1
<input type="checkbox"/> >3 yrs/never      0	<input type="checkbox"/> none      0	<input type="checkbox"/> none      0	<input type="checkbox"/> low	0	0
<input type="checkbox"/> don't know      ?	<input type="checkbox"/> don't know      ?	<input type="checkbox"/> don't know      ?	<input type="checkbox"/> don't know		?

This question looks at how well the weed can reproduce, to rapidly build up its numbers at a site, and to spread quickly to other sites. If a weed never gets to reproduce in a landuse then it will score 0. Three factors are considered in scoring the weed:

- Time to seeding is the time from establishment (from seed or vegetative propagules) to seed production.
- Consider seed set as the average number of viable seed produced per square metre of ground per year, in a patch of the weed. This may be from one large weed (e.g. a tree) or many small weeds (e.g. grasses). High would be >1000 seeds per m<sup>2</sup>. Your answer to question 2 may influence seed set.
- Consider vegetative reproduction as the average number of new plants produced each year by such means as bulbs, bulbils, corms, tubers, rhizomes, stolons, root suckers, root fragments and shoot fragments. High would be >10 new plants per year from a mature parent plant. In certain landuses cultivation may increase vegetative reproduction (e.g. Lincoln weed). "New plants" are defined as shoots with their own root system. There may still be some connection to the parent plant (e.g. couchgrass).

3. How likely is long-distance dispersal (>100m) by natural means?				Total (a+b+c+d)	SCORE
<b>(a) Flying birds</b>		<b>(b) Other wild animals</b>		6, 7 or 8	3
<input type="checkbox"/> common	2	<input type="checkbox"/> common	2	3, 4 or 5	2
<input type="checkbox"/> occasional	1	<input type="checkbox"/> occasional	1	1 or 2	1
<input type="checkbox"/> unlikely	0	<input type="checkbox"/> unlikely	0	0	0
<input type="checkbox"/> don't know	?	<input type="checkbox"/> don't know	?		?
<b>(c) Water</b>		<b>(d) Wind</b>			
<input type="checkbox"/> common	2	<input type="checkbox"/> common	2		
<input type="checkbox"/> occasional	1	<input type="checkbox"/> occasional	1		
<input type="checkbox"/> unlikely	0	<input type="checkbox"/> unlikely	0		
<input type="checkbox"/> don't know	?	<input type="checkbox"/> don't know	?		

This question looks at how well the weed can spread its propagules (seed or vegetative) by natural means, to start new weed outbreaks a long distance from the original outbreak. Weeds which have more means of dispersal tend to spread faster. Consider if a weed is adapted for long-distance dispersal by any of the above means, and how regularly these means of dispersal occur. How often do you see new outbreaks starting at least 100 metres away from an original infestation?

Features favouring long-distance dispersal by flying birds and other wild animals (e.g. foxes, kangaroos, rabbits, emus) are:

- whole fruits are eaten, and viable seeds are then defecated or regurgitated (e.g. olives, sweet briar)
- propagules have hooks, barbs or sticky substances that attach to feathers, hairs or skin (e.g. horehound, brome grass)
- very small seeds which can lodge within feathers, hairs or feet (e.g. nutgrass)

Features favouring long-distance water dispersal are:

- propagules which float (consider wind-assisted movement as water dispersal)
- weeds located in or near to moving water
- frequent floods

Mainly aquatic weeds such as salvinia and seeding willows would be commonly dispersed over 100m by water movement.

Research has shown that seeds of most wind dispersed weeds actually land close to the parent plants. Long-distance dispersal is more likely to be common for tall trees with light seeds (with wings, plumes or hairs) which are subject to frequent strong winds, and for weeds which snap off after fruiting and roll across sparsely-vegetated ground (e.g. wild turnip, serrated tussock).



4. How likely is long-distance dispersal (>100m) by human means?		Total (a+b+c+d)	SCORE
<b>(a) Deliberate spread by people</b>		6, 7 or 8	3
<input type="checkbox"/> common	2		
<input type="checkbox"/> occasional	1		
<input type="checkbox"/> unlikely	0		
<input type="checkbox"/> don't know	?		
<b>(b) Accidentally by people and vehicles</b>		3, 4 or 5	2
<input type="checkbox"/> common	2		
<input type="checkbox"/> occasional	1		
<input type="checkbox"/> unlikely	0		
<input type="checkbox"/> don't know	?		
<b>(c) Contaminated produce</b>		1 or 2	1
<input type="checkbox"/> common	2		
<input type="checkbox"/> occasional	1		
<input type="checkbox"/> unlikely	0		
<input type="checkbox"/> don't know	?		
<b>(d) Domestic/farm animals</b>		0	0
<input type="checkbox"/> common	2		
<input type="checkbox"/> occasional	1		
<input type="checkbox"/> unlikely	0		
<input type="checkbox"/> don't know	?		
		0	?

This question looks at how well the weed can spread its propagules (seed or vegetative) by human-influenced means, to start new weed outbreaks a long distance from the original outbreak. Weeds which have more means of dispersal tend to spread faster. Consider if a weed is adapted for long-distance dispersal by any of the above means, and how regularly these means of dispersal occur. How often do you see new outbreaks starting at least 100 metres away from an original infestation?

Deliberate human spread includes weeds which are currently or have been historically planted for use in agriculture, forestry, horticulture, amenity, windbreaks and/or soil protection. **Ignore the landuse for this question.** Examples include olives, African lovegrass and Aleppo pine. Deliberate human spread also includes weeds with attractive flowers which are picked and then discarded (e.g. Calomba daisy, cape tulip). A weed may be legally restricted from sale, but is it still planted?

Features favouring accidental people and vehicle dispersal are:

- weeds which grow in heavily trafficked areas, such that transport by footwear, clothing or vehicles (including farm machinery and boats) may occur
- weeds which are dragged by farm machinery (e.g. silverleaf nightshade)
- propagules have hooks, barbs, or sticky substances to attach to objects (e.g. caltrop)
- very small propagules which can lodge in cracks in footwear, clothing or vehicles (e.g. Lincoln weed)

For contaminated produce consider crop seed, pasture seed, hay, soil, gravel, fertilisers, manures, and/or mulch. Examples of weeds which may be commonly spread by such means include bifora, salvation Jane, and soursob. Do not consider wool as this relates to the sale of farm animals between properties, which is covered in (d).

Features favouring dispersal by domestic/farm animals (e.g. sheep, cattle, horses, dogs) are:

- whole fruits are eaten, and viable seeds are then defecated or regurgitated (e.g. cutleaf mignonette, charlock)
- propagules have hooks, barbs or sticky substances that attach to feathers, hairs or skin (e.g. horehound, brome grass)
- very small seeds which can lodge within feathers, hairs or feet (e.g. nutgrass)

## IMPACTS

This section indicates the **potential impacts** the weed has. Each question is answered with a landuse in mind. Assume that the **weed has spread** across a whole paddock, orchard, plantation, nature reserve or water body, and that **commonly-used weed management practices have not been changed to specifically target the weed**. If the weed is well-controlled by these common practices then it will occur at a low density and will have minimal impacts. Alternatively, if the weed is poorly controlled by these common practices then it may get to a high density and have substantial impacts. If the weed has an effective biocontrol agent established which substantially reduces its growth then the weed's impacts will be reduced. **Decide if the weed is likely to reach a low, medium or high density in the landuse.**

1. Does the weed reduce the establishment of desired plants?		SCORE
<input type="checkbox"/> >50% reduction	The weed stops the establishment of more than 50% of desired plants (e.g. regenerating pasture, sown crops, planted trees, regenerating native vegetation), by preventing germination and/or killing seedlings.	3
<input type="checkbox"/> 10-50% reduction	The weed stops the establishment of between 10% and 50% of desired plants.	2
<input type="checkbox"/> <10% reduction	The weed stops the establishment of less than 10% of desired plants.	1
<input type="checkbox"/> none	The weed does not affect the germination and seedling survival of desired plants.	0
<input type="checkbox"/> don't know		?

*This question looks at whether the weed prevents the establishment of desired plants, so the density of these plants is reduced. The weed may prevent germination by dense shading, or by forming physical barriers to water movement into the soil. The weed may kill seedlings by denying them access to soil moisture, sunlight and nutrients.*

*Note that the desired plants may mainly establish after a major disturbance (e.g. cultivation prior to planting, bushfire), so the weed itself may also be establishing. In these cases does the weed actually have a major effect?*

*Weeds which are likely to cause over 50% reductions in establishment are gorse and early-germinating (and unsprayed) salvation Jane in pastures, and phlaris and watsonia in native vegetation.*

3. Does the weed reduce the yield or amount of desired vegetation?		SCORE
<input type="checkbox"/> >50% reduction	The weed reduces crop, pasture or forestry yield, or the amount of mature native vegetation by over 50%.	4
<input type="checkbox"/> 25-50% reduction	The weed reduces yield or amount of desired vegetation by between 25% and 50%.	3
<input type="checkbox"/> 10-25% reduction	The weed reduces yield or amount of desired vegetation by between 10% and 25%.	2
<input type="checkbox"/> <10% reduction	The weed reduces yield or amount of desired vegetation by up to 10%.	1
<input type="checkbox"/> none	The weed has no effect on growth of the desired vegetation. Or the weed may become desirable vegetation at certain times of year (e.g. providing useful summer feed), which balances out its reduction in the growth of other desirable plants.	0
<input type="checkbox"/> don't know		?

This question looks at the degree of yield loss (in crops, pastures, forestry) or suppression (in mature native vegetation) caused by the weed. It follows on from question 1, and looks at the growth achieved by plants which did establish despite the weed. The question is answered on a per hectare basis, in comparison to similar vegetation which is free of the weed. For native vegetation it may be useful to think in terms of percentage cover.

Weeds will reduce growth of other plants by competing for sunlight, water and nutrients. Competition is greater where a weed is larger (e.g. tall with a dense leaf canopy and an extensive root system) and grows at the same time as the desirable plants. Some weeds also compete by forming physical barriers which stop plants growing to reach light, water and/or nutrients (e.g. tuber mat of bridal creeper). A special case are parasitic weeds which directly attack other plants. Weeds which could cause >50% reductions in the yield/amount of desired vegetation would include Aleppo pines, serrated tussock and branched broomrape.

Some weeds may increase the amount of useful vegetation in a landuse. For example, does a perennial weed of grazing land provide nutritious summer feed, thus increasing total pasture available throughout the year?

4. Does the weed reduce the quality of products or services obtained from the landuse?		SCORE
<input type="checkbox"/> high	The weed severely reduces product quality such that it cannot be sold. This may be due to severe contamination, toxicity, tainting and/or abnormalities (chemical and/or physical). For <b>native vegetation</b> , the weed severely reduces biodiversity (plants and animals) such that it is not suitable for nature conservation and/or nature-based tourism. For <b>urban</b> areas, the weed causes severe structural damage to physical infrastructure such as buildings, roads and footpaths.	3
<input type="checkbox"/> medium	The weed substantially reduces product quality such that it is sold at a much lower price for a low grade use. For <b>native vegetation</b> , the weed substantially reduces biodiversity such that it is given lower priority for nature conservation and/or nature-based tourism. For <b>urban</b> areas, the weed causes some structural damage to physical infrastructure such as buildings, roads and footpaths.	2
<input type="checkbox"/> low	The weed slightly reduces product quality, lowering its price but still passing as first grade product. For <b>native vegetation</b> , the weed has only marginal effects on biodiversity but is visually obvious and degrades the natural appearance of the landscape. For <b>urban</b> areas, the weed causes negligible structural damage, but reduces the aesthetics of an area through untidy visual appearance and/or unpleasant odour.	1
<input type="checkbox"/> none	The weed does not effect the quality of products or services.	0
<input type="checkbox"/> don't know		?

This question looks at whether the weed effects the quality of products or services obtained from a landuse. Products affected by the weed may include meat, grain/seed, milk, wool, timber, fruit, hay, and/or water. For native vegetation, consider services such as nature conservation and tourism. An example of a high effect on quality is dodder preventing the sale of seed crops. Reduction in stock condition/live weight should not be considered here - this is due to either a reduction in available feed (question 2) or animal health effects caused by eating the weed (question 5).

For this question, ignore a weed's proclamation status with regard to moving contaminated produce in South Australia, but do consider noxious weed lists and seed quality standards of other states or countries. This prevents bias against non-proclaimed weeds when comparing them to existing proclaimed plants.

5. Does the weed restrict the physical movement of people, animals, vehicles, machinery and/or water?	SCORE
-------------------------------------------------------------------------------------------------------	-------

<input type="checkbox"/> <b>high</b>	Weed infestations are impenetrable throughout the year, preventing the physical movement of people, animals, vehicles, machinery and/or water.	3
<input type="checkbox"/> <b>medium</b>	Weed infestations are rarely impenetrable, but do significantly slow the physical movement of people, animals, vehicles, machinery and/or water throughout the year.	2
<input type="checkbox"/> <b>low</b>	Weed infestations are never impenetrable, but do significantly slow the physical movement of people, animals, vehicles, machinery and/or water at certain times of the year <b>or</b> provide a minor obstruction throughout the year.	1
<input type="checkbox"/> <b>none</b>	The weed has no effect on physical movement.	0
<input type="checkbox"/> <b>don't know</b>		?

*This question looks at the degree to which a dense infestation of the weed physically restricts movement. Weeds may restrict movement by being tall, thorny, tangled and/or dense. For this question, ignore any deliberate restrictions on movement aimed solely at limiting the spread of weed propagules.*

*Examples of weed limits on movement include:*

- *slowing of stock mustering*
- *blockages of farm machinery at crop sowing and/or harvesting*
- *tyre punctures*
- *slowing of water flow in irrigation systems*
- *interference with boat access*
- *interference with thinning operations in forestry*
- *preventing stock access to pasture and/or water*
- *preventing animal access to nesting sites*

*Weeds which would score highly include blackberry and gorse at high densities, forming impenetrable thickets.*

<b>6. Does the weed affect the health of animals and/or people?</b>		<b>SCORE</b>
<input type="checkbox"/> <b>high</b>	The weed is highly toxic and frequently causes death and/or severe illness in people, stock, and/or native animals.	3
<input type="checkbox"/> <b>medium</b>	The weed occasionally causes significant physical injuries (due to spines or barbs) and/or significant illness (chronic poisoning, strong allergies) in people, stock, and/or native animals, occasionally resulting in death.	2
<input type="checkbox"/> <b>low</b>	The weed can cause slight physical injuries or mild illness in people, stock, and/or native animals, with no lasting effects.	1
<input type="checkbox"/> <b>none</b>	The weed does not affect the health of animals or people.	0
<input type="checkbox"/> <b>don't know</b>		?

*This question looks at how the weed affects the health of animals (domestic stock and native) and people. Note that if a weed is toxic but is not palatable then it may not actually be grazed. Ignore any starvation effects from reduced growth of pasture or reduced access to pasture, as these have been covered in questions 2 and 4. A weed with high effects on health would be poison ivy.*

<b>7. Does the weed have major, positive or negative effects on environmental health?</b>
-------------------------------------------------------------------------------------------

	<input type="checkbox"/> major positive effect	<input type="checkbox"/> major negative effect	<input type="checkbox"/> minor or no effect	<input type="checkbox"/> don't know
scoring for (a) - (f):	-1	1	0	?
<b>(a) food/shelter ?</b>	<i>Examples of negative effects are blackberry harbouring rabbits and grass weeds hosting wheat root diseases. An example positive effect is boxthorn providing stock shelter. Ignore pasture for livestock as this was covered in question 2.</i>			
<b>(b) fire regime?</b>	<i>This includes changes to the normal frequency, intensity, and/or timing of fires. Examples of weeds having major effects include exotic grasses invading shrubby native vegetation.</i>			
<b>(c) increase nutrient levels?</b>	<i>For example, legumes can increase soil nitrogen. This may make native vegetation more prone to invasion by other weeds, but would be beneficial in agriculture. Ignore competition for nutrients (decreased nutrient levels) as this was covered indirectly in question 2.</i>			
<b>(d) soil salinity?</b>	<i>Are the leaves of the weed high in salt? Leaf decomposition may increase salinity at the soil surface. Example plants are iceplant and tamarix.</i>			
<b>(e) soil stability?</b>	<i>Does the weed increase soil erosion, or silting of waterways?</i>			
<b>(f) soil water table?</b>	<i>Does the weed substantially raise or lower the soil water table compared to other plants present? Is this positive or negative? Ignore competition for water as this was covered in question 2.</i>			
Total (a + b + c + d + e + f)	>3	2 or 3	1	0 or less
SCORE FOR 6.	3	2	1	0

*This question looks at whether the weed has major, long-term effects on a landuse's environment. These effects may be beneficial or detrimental. Effects are more likely where the weed substantially changes the vegetation structure, such as woody weed invasion of grassland. Decisions on major effects should be well-known (e.g. backed up by scientific studies or expert opinion).*

## POTENTIAL DISTRIBUTION

This section looks at what proportion of a landuse is at risk from the weed in question. This will depend on the **climate and soil preferences of the weed**. For example, some weeds may only be suited to higher rainfall areas of a Board, or only be a problem on alkaline soils. **Differences within the landuse also need to be considered**. For example in the perennial horticulture landuse, a weed may be a problem in citrus but not occur in vineyards. This score should also be based on where the weed will grow at the density you assumed in scoring Impacts. That is, if you assumed a high density in scoring impacts then ignore areas where the weed would only persist at a low density when determining potential distribution

This question is best answered with topographic, landuse and soil maps for the Board area. These can be analysed electronically using a GIS system such as ArcView, or done on paper maps. Data and maps can be obtained from PIRSA. If using maps the following steps will help in estimating the percentage area of a landuse that is suitable for the weed:

1. Map the landuse in your Board. If you do not have a landuse map, you could shade areas on clear plastic laid over topographic maps.
2. Consider the climatic and soil preferences of the weed, and the vegetation/crop/pasture types within the landuse to which the weed is suited. Lay a sheet of plastic over the landuse map, and shade the areas of the landuse which are suitable for the weed.
3. Compare the weed's map to the landuse map to estimate the percentage of the landuse which is suitable for the weed. Answer as follows:

In the Board, what area of the landuse is suitable for the weed?		SCORE
<input type="checkbox"/> > 80% of landuse	The weed has a potential to spread to more than 80% of the landuse in the Board.	10
<input type="checkbox"/> 60-80% of landuse	The weed has a potential to spread to between 60% and 80% of the landuse in the Board.	8
<input type="checkbox"/> 40-60% of landuse	The weed has a potential to spread to between 40% and 60% of the landuse in the Board.	6
<input type="checkbox"/> 20-40% of landuse	The weed has a potential to spread to between 20% and 40% of the landuse in the Board.	4
<input type="checkbox"/> 10-20% of landuse	The weed has a potential to spread to between 10% and 20% of the landuse in the Board.	2
<input type="checkbox"/> 5-10% of landuse	The weed has a potential to spread to between 5% and 10% of the landuse in the Board.	1
<input type="checkbox"/> 1-5% of landuse	The weed has a potential to spread to between 1% and 5% of the landuse in the Board.	0.5
<input type="checkbox"/> unsuited to landuse	The weed is not suited to growing in any part of the landuse in the Board.	0
<input type="checkbox"/> don't know		?

# WEED IMPORTANCE SCORE

The score for weed importance is calculated by adjusting the invasiveness, impacts and potential distribution scores to range from 0 to 10, and then multiplying these. The spreadsheet does this for you. The logic of multiplying is described below.

**To calculate manually then adjust the raw scores as follows:**

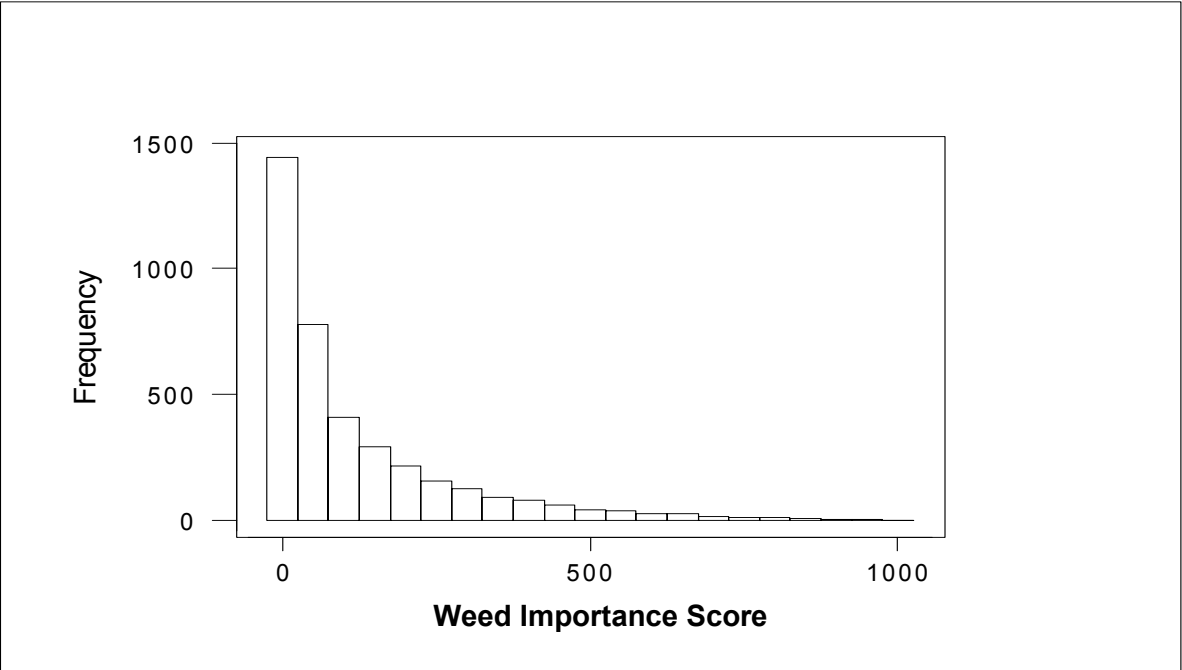
Invasiveness:                      Divide by 15 and multiply by 10. Round off to one decimal place.

Impacts:                              Divide by 19, and multiply by 10. Round off to one decimal place.

Potential distribution:              Leave unchanged.

**Weed Importance = Invasiveness × Impacts × Potential distribution**

Weed importance will have a maximum of 1000, and a minimum of 0. The figure below shows the frequency of possible scores:



Splitting up these possible scores into bands of 20% gives cut-offs for classes of weed importance:

<b>FREQUENCY BAND</b>	<b>Weed Importance Score</b>	<b>Weed Risk</b>
80 - 100% (top 20% of possible scores)	209+	<i>Very high</i>
60 - 80%	< 209	<i>High</i>
40 - 60%	< 84	<i>Medium</i>
20 - 40%	< 29	<i>Low</i>
0 - 20% (bottom 20% of possible scores)	< 3	<i>Negligible</i>

**Do not compare scores between landuses.** Landuses differ in their value and this is hard to measure. Also, average weed importance scores may be lower in agricultural landuses compared to other landuses. This is simply because of the greater level of weed management in agriculture. It does not mean that agricultural weeds are less important.

**Why multiply the invasiveness, impacts and potential distribution scores?**

- Multiplying gives a greater spread in the scores than adding (i.e. range from 0-1000 compared to 0-30).
- Multiplying is logical, as it recognises the interactions between the criteria. Say the impacts of a weed can be measured in dollars per hectare per year, the potential distribution is known in hectares, and the invasiveness (i.e. rate of spread) is measured in terms of the increase in hectares compared to the previous year:

$$\begin{array}{ccccc}
 \text{Impact} & & \times & & \text{Potential Distribution} & & \times & & \text{Invasiveness} \\
 & & & & & & & & \\
 \$ / \text{hectares} / \text{year} & & & & \text{hectares} & & & & \text{hectares}(\text{current year}) / \text{hectares} \\
 (\text{previous year}) & & & & & & & & 
 \end{array}$$

When multiplying, all of the hectares units cancel so that weed importance is measured in total dollars per year. In multiplying the invasiveness, impacts and potential distribution criteria scores, we are mimicking the above calculation, without having the actual dollar and hectare figures.