Australian Government
Land & Water Australia

ThinkingBush ThinkingWeeds

Knowledge for managing native vegetation in Australian landscapes

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Defeating the Weed Menace R & D

BIOCONTROL
DETECTION AND SPREAD
CLIMATE CHANGE
MANAGEMENT TOOLS
AQUATIC WEEDS
PERI-URBANISATION
LAND USE

NATIVE VEGETATION AND BIODIVERSITY R & D PROGRAM

CONTENTS

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Coming Events

10th Queensland Weed Symposium
Managing weeds in a climate of change
The Weed Society of Queensland
26–29 July 2009
Capricorn Resort, Yeppoon Qld
www.wsq.org.au

15th NSW Biennial Weeds Conference
The Old and the New
(Changes in Weed Management)
15–17 September 2009
The Crossing Theatre, Narrabri NSW
www.weedsconference.com

4th Victorian Weed Conference
Plants behaving badly in agriculture
and the environment
The Weed Society of Victoria
7–8 October 2009
Mercure Hotel, Geelong VIC
www.wsvic.org.au

Jim Donaldson, Executive Manager, Sustainable Landscapes, Land & Water Australia

Foreword

This is a special issue of *Thinking Bush* which presents the findings of some of the research projects completed as part of the Defeating the Weed Menace R&D program that we think are most pertinent to those practitioners with a keen interest in vegetation management and landscape restoration.

The impacts of weeds on rural production and our natural ecosystems are regularly identified as major concerns in natural resource management in Australia. The Australian Bureau of Statistics tells us that farmers spend more on weed management than on pests and land and soil problems combined. In 2006-07, $1.6 billion is estimated to have been spent on weeds, with over $980 million on herbicide alone.

Increasingly, there is recognition of the need to take an integrated and landscape approach to managing weeds and to focus on the broader context and ultimate outcomes we are seeking to achieve by controlling weeds, be that to improve agricultural productivity or restore natural ecosystems to a healthy state. With financial resources always going to be a constraint, greater attention is also being paid to assessing risks and prioritising weed management problems, as well as developing methods to monitor and evaluate the outcomes of on-ground activities better.

These challenges in managing weeds are recognised through the extent to which weed issues are incorporated into various parts of the Australian Government's 'Caring for Our Country' Business Plan for 2009-10. The Australian Weeds Strategy, released in 2007, demonstrates a similar focus on undertaking actions to strategically protect the key assets and things we value rather than adopting a broad untargeted approach.

Research is critical to support more targeted policies, investment and actions to address weed management problems. Since 2006, Land & Water Australia has managed a national weeds research program on behalf of the Australian Government's Defeating the Weed Menace program. Details of the projects funded under this program can be found at: **lwa.gov.au/weeds**

One of the strong messages emerging from the past three years of research is the extent to which both research and subsequent management of weeds would benefit from greater collaboration between weeds research teams and land managers — for example, to understand the problems, plan and prioritise actions, and design robust approaches to monitoring success. It is incumbent on us all to help make this happen.

With the wrap-up of both the CRC for Australian Weed Research (**www.weedscrc.org.au**) and the National Land & Water Resources Audit (see **www.nlwra.gov.au**) there is a large volume of weeds research information now available, all of it directed to improving weed management in Australia. State and territory agriculture, natural resource and environment agencies, CSIRO, universities and many others have contributed to generating this considerable information base. The establishment of the new Australian Weeds Research Centre by the Australian Government offers a renewed opportunity to continue to build upon these sound foundations and forge new partnerships to generate and share the knowledge needed to prevent, reduce and manage the impacts of weeds.

We hope you find the range of articles in this edition of *Thinking Bush* both interesting and inspiring.

When is a native seed a weed?

Penny Atkinson, Greening Australia Limited

Florabank is a national program run by Greening Australia to provide information for seed users and suppliers, ensure seed science is made available to the native seed sector, and to bring the native seed industry closer together to improve the diversity, quality and quantity of native seed available in Australia.

A seed is a small package that miraculously germinates into a new life. Thinking of native seeds generally brings a happy glow to most people who work on restoration projects (unless they are having trouble sourcing the right seeds for the job!). But a native seed can be a weed if the wrong seed is planted in the wrong place.

To minimize biodiversity risks, restoration projects in Australia generally require that local native species are used. However, the definition of 'local' is imprecise, and Florabank has now introduced a new way of thinking to help people to appropriately source seed ("There's more to seed than local provenance" *Thinking Bush* 7 October 2008), as well as some interactive web-tools to assist people to make these decisions (*Species Navigator* and the *Seed Collection Advisor* are available on **www.florabank.org.au**).

Where seeds from the right range of species in the local area are not available in enough quantity for planned restoration projects, one of two things can happen which may have negative consequences:

1) seed is only sourced from small local populations with poor genetic diversity, potentially causing problems for the success and vigour of the resulting plants (Broadhurst, 2007)
2) seed is brought in from further away or from unknown sources to fill the order, potentially causing problems for the genetic integrity of natural populations, or for the success of the project.

When seed from a species is collected from sites where the environment significantly differs from the planting site (for example, where the altitude, soil type, temperature or rainfall is very different), it is likely that there has been plant adaptive variation between the sites, and the seed from the source site may not suit the planting site.

When sourcing seed, it's easily assumed that if you have the right species, you're right to go. But many species contain multiple sub-taxa (Box 1), or have significant provenance variation across their distribution range (Box 2).

For these reasons, it is best to use local seeds if they come from similar sites and have good physical and genetic quality. You must get the taxonomy of your seed right to avoid problems, and the more you know about exactly where the seed came from, the better off you are.

Weeds can be introduced to your restoration site by using poor quality seed. Weed seeds can be hidden in a poor-quality seed lot. This is why using good, clean seed from a reputable supplier or experienced seed collector with good plant identification skills is important. Some native species look similar to weed species to the untrained eye, so seed collecting mistakes can happen.

Florabank is working with the native seed sector to improve access to the right seed for the right purpose. Florabank aims to increase the capacity of the native seed sector to meet the increasing demand for seed for revegetation projects around Australia. Florabank has also developed and delivers specialist training for people working with native seed.

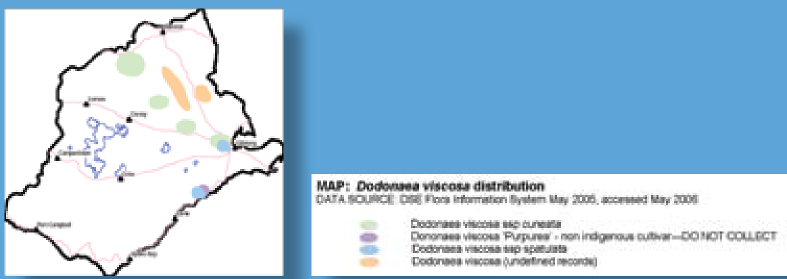
From 2009, Florabank will be working with the native seed industry to develop and deliver an accreditation and certification program for the industry. This will help to ensure that the seed people buy from accredited suppliers is free from weed seeds, and that the seed is sourced appropriately to the planting location so that it doesn't become a weed!

For more information about Florabank, visit our website **www.florabank.org.au**, email us at *general@florabank.org.au* or call us at Greening Australia on 02 6202 1600.

Greening Australia

Box 1: Dodonaea viscosa

Dodonaea viscosa is a widespread species commonly used in restoration projects. However, the species has seven sub-species that are widely distributed, and in some cases these have overlapping distributions. Simply planting "*Dodonaea viscosa*" seed sourced without any attention to the sub-species could mean that the wrong plants are being introduced. Florabank recommends that you look further than the species name, and find out if there are sub-taxa, to ensure that you are planting not only the right species, but the right subspecies or variety for your local site. *Species Navigator* **www.florabank.org.au** can assist you with this research for over 100 common restoration species. Over the next few years, with the support of regional sponsors, we hope to increase the number of species on this informative web-tool to 600 of Australia's most commonly used restoration species.



Box 2: Acacia dealbata

Acacia dealbata has characteristics that put it at high risk of weediness, including the ability to sucker, and it has become a weed in several locations in Australia where it does not occur naturally (for example, South-West WA and in southern parts of South Australia). There are two forms of this species within the Corangamite NRM Region of Victoria.

For *A.dealbata*, hybridisation is a distinct risk to natural remnant populations (Nuttal *et al.*, 2006). Species can be at risk of hybridisation or genetic contamination from closely related species or non-local nursery varieties that are substituted for local plants (Nuttal *et al.*, 2007). Using the wrong provenance of this species could cause problems for the natural populations and for remnant vegetation.

References

Broadhurst LM (2007) **Managing Genetic Diversity in Remnant Vegetation: Implications for Local Provenance Seed Selection and Landscape Restoration.** **lwa.gov.au/products/pk071323**

Carr D (2008) **There's more to seed than local provenance** *Thinking Bush* 7 October 2008. **lwa.gov.au/nativevegetation**

Nuttal et. al CSSRN (2006 and 2007) **Corangamite Region Guidelines: Corangamite Seed Supply and Revegetation Network**, Individual Species Fact Sheets, 3pp. **http://www.florabank.org.au/default.asp?V_DOC_ID=891**

For further details, go to: **www.wsq.org.au**

Weeds research in a changing world

Judy Lambert, National Weeds R&D Coordinator, Land & Water Australia

Between 2004 and 2008 the Australian Government committed $44.4 million to the national Defeating the Weed Menace program to identify Australia's most threatening weeds and to implement measures for their control.

A research and development (R&D) component of the program was managed by Land & Water Australia on behalf of the Department of Agriculture, Fisheries and Forestry and the Department of the Environment, Water, Heritage and the Arts . The goal of this 2–year R&D component was to generate new knowledge to prevent the development of new weed problems, to reduce the impacts of existing weeds of national priority, and to build capacity for their management into the future.

Between June 2006 and November 2008, 27 projects were directed towards:

- assessing risks of different pathways of weed ingress
- assessing impacts of land use change on weed incursion
- developing 'best practice' early detection, survey and eradication of potential weed species
- identifying biocontrol agents for priority weed species
- developing new integrated weed management strategies that incorporate an understanding of landscape scale ecological processes
- quantifying the impacts of weeds on sustainability and the environment (including the ecological costs of weeds) and the relative benefits and costs of different weed control measures
- providing knowledge to support a national information system for weeds
- developing a framework to improve the targeting of weed biological control projects.

A key focus of the R&D has been the generation of knowledge products designed to maximise uptake of the information generated. As the program draws to a close in April 2009, key cross-project learnings will be highlighted and input relevant to future weeds R&D at the national level identified.

Dr Judy Lambert is the principal of a small consultancy business, Community Solutions. Judy's training in a diversity of disciplines and her emphasis on integrating biodiversity conservation and rural production has seen her serve for the past 2–3 years as the National Weeds R&D Coordinator hosted by Land & Water Australia.

The new stewards of the peri-urban landscape

Darryl Low Choy, Griffith University; and Jo Harding, ACT NRM, for the Upper Murrumbidgee Catchment Coordinating Committee

The fringes of our cities and urban settlements have undergone a rapid and complete makeover in recent years. These transformed landscapes bear little resemblance to the former countryside and are now inhabited by a completely new range of residents who have different motivations, skills and capacity to manage the land.

Recent research[1] has highlighted the long-standing challenges of managing the rapid and unabated growth on the fringes of our metropolitan and urban centres — the peri-urban areas. The *Change and Continuity in Peri-urban Australia* research project has redefined the peri-urbanisation process as a dynamic urbanising process that involves the closer subdivision, fragmentation and land use conversion of former rural lands. It entails high levels of non-metropolitan growth and results in a blurred transitional zone comprised of temporary mixes of urban and rural activities and functions. The resulting peri-urban land use activities exhibit a high degree of variety, and when combined with frequent land-use change and conflicting values, make these areas extremely difficult to manage by conventional and traditional means.

These peri-urban areas lie within the sphere of influence of nearby metropolitan or urban centres and display a variety of dependencies on these centres for economic, social and cultural purposes. The study highlighted the significant demographic changes that these areas have experienced.

These changes have resulted in a wave of new settlers now being largely responsible for the management of freehold peri-urban landscapes. Future management initiatives, especially in the natural resource management (NRM) area, will have to engage this raft of new actors on the peri-urban stage.

These 'actors' have been categorised as:

- *the Seekers*: including "tree/sea change" life stylers, "blockies/ homesteaders", religious communities and alternative life stylers.
- *the Survivors*: including DIY home builders, the horse community, "truckies" and "adaptive" farmers
- *the Speculators*: including farm stays and retreats, the pet industry, boutique farmers, recreational providers, landscape suppliers, the equine industry, developers and real estate agents
- *the Strugglers*: characterised by the "holding-on" farmers.

The research recognised that the range of landscape management challenges associated with the peri-urbanisation process comprised: loss of biodiversity (including loss of habitat), infestation of weeds and pest animals, loss of scenic amenity, a decline in water quality, changes to hydrological regimes, significant impacts to groundwater resources, potential high bushfire hazards (especially to rural residents), questionable landscape management capability and capacity of new peri-urban settlers, as well as a raft of associated social and economic challenges.

Future environmental and natural resource management initiatives will have to engage this range of new private landowners who have settled into peri-urban landscape settings, and who now have stewardship responsibilities for increasing portions of these areas.

Note

1 *Research project:* ***Change and Continuity in Peri-urban Australia****, Monographs 1, 2, 3 & 4, Griffith University and RMIT University for Land & Water Australia.*

The challenge for those charged with developing appropriate response measures will be to establish approaches that can account for the confusing milieu of peri-urban land uses, community values and aspirations. These will bear little resemblance to past approaches. The complexity of peri-urban land use activities will necessitate the delivery of resource management actions through a range of appropriate institutional arrangements. This will then require a far more coordinated approach from all levels of government, industry, the community and private landholders than has been seen as yet.

To this end, future management initiatives need to focus on the process of peri-urbanisation and not solely on its spatial dimensions. Such initiatives can be focused through utilising peri-urbanisation management cycles that highlight the critical linkages between the drivers of change, the peri-urban process and its resulting management challenges, and the new 'actors' on the peri-urban scene. A number of peri-urban management cycles have been developed to illustrate this approach, including an equine landscape (leading to landscape management challenges, see figure 1).

Controlling invasive weeds was always a key landscape management challenge for the farmers who previously occupied these former rural lands. Whilst weed management continues to be a major ongoing management challenge for these areas, the required response is now much more complicated given the shift in stewardship responsibility to the new 'actors' on the peri-urban stage as previously noted. This is the focus of the research project *Exploring Agents of Change to Peri-urban Weed Management*, being undertaken by Upper Murrumbidgee Catchment Coordinating Committee (UMCCC) with support from Griffith University.

This study is examining the peri-urban areas in the Upper Murrumbidgee catchment near Canberra to determine the drivers to land use change in relation to invasive weeds. The study's key research questions include:

1. What drivers of change are influential in attracting the new wave of peri-urban dwellers (rural lifestylers) to these locations and what are the characteristics of the lifestyles they are pursuing?
2. Are these drivers and trends likely to continue in the near future?
3. What are the priority weeds management challenges for existing peri-urban areas?
4. Do rural lifestylers have the necessary motivation, capability and capacity to properly address existing and emergent NRM issues, particularly invasive weeds, on their properties?
5. Do rural lifestylers have well developed networks that can be utilised to inform and disseminate important NRM information and messages on weeds through their peri-urban communities?

The research outcomes will provide greater clarity of the contemporary peri-urban processes and their drivers, and potentially lead to improved and more robust landscape and weeds management. The findings will provide important input into future weed management strategies and aid in the development of efficient methods for surveying and eradicating emergent weeds in these rapidly peri-urbanising areas.

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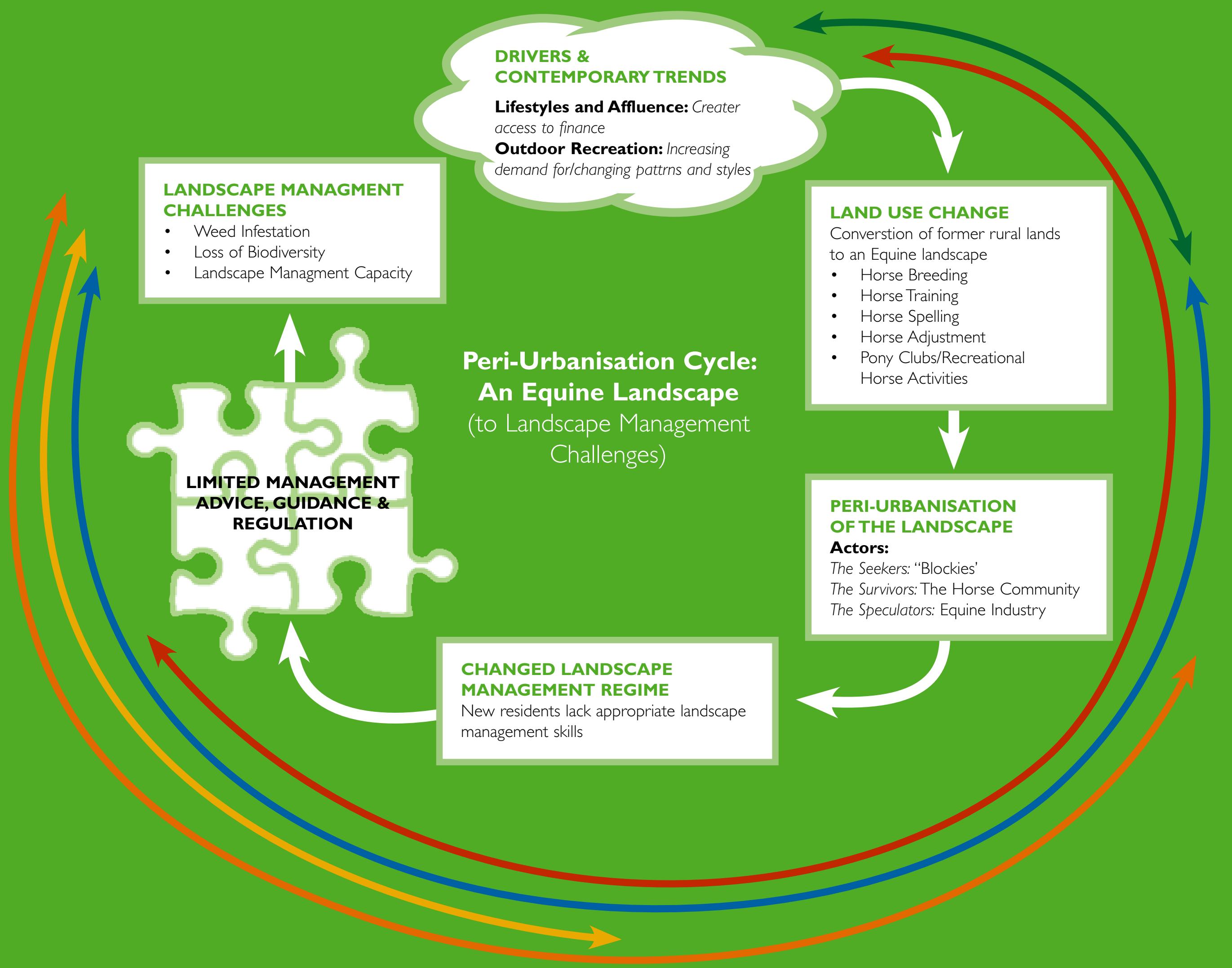
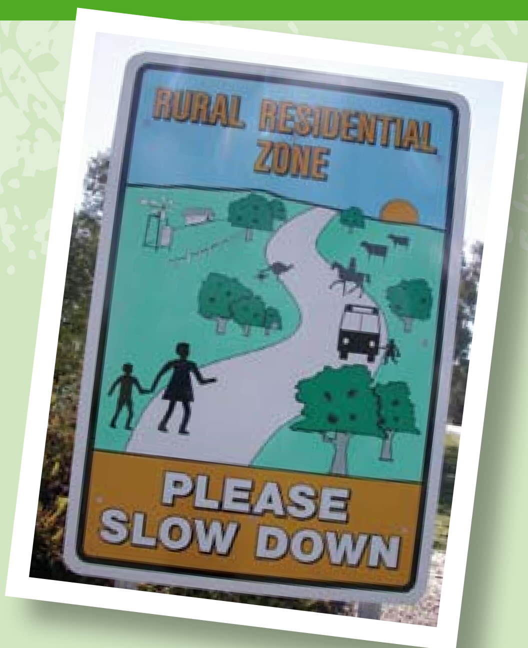
Peri-urbanising former rural landscapes at Murrumbateman and Womboin, in the upper Murrumbidgee Catchment near Canberra. Photos by Darryl Low Choy and Jo Harding

Figure 1
Peri-Urbanisation Cycle: An Equine Landscape (leading to landscape management challenges)



Potential Opportunities for Policy/Planning Intervention
National Government · State Government · Local Government · Industry · Non-Government (NGO's) or Community Based Organisations (CBO's)



A typical peri-urban landscape centred on equine activities.
Photo by Darryl Low-Choy

A commentary on nationally funded biological control projects

Bruce Auld, Science Adviser to Defeating the Weed Menace R&D

Overview

In a suite of 27 national weeds research projects funded as part of the Defeating the Weed Menace R&D program, Land & Water Australia funded seven projects under the theme of "Biocontrol agents for national priority weeds".

The projects related to weeds in all states and territories and included insects and fungi as control agents and embraced the whole range of activities involved in classical biological control of weeds:

CEN7 Enhancing Noogoora Burr Biocontrol in Northern Australia

CEN8 Boneseed Rust: A Highly Promising Candidate for Biological Control

CEN11 Biological Control and Ecology of Alligator Weed

CEN12 Development of New Biocontrol Agents for Parkinsonia

SARDI1 Importation, Rearing and Field Release of the Cape Broom Psyllid

UWO7 Improving Management of Salvinia in Temperate Aquatic Ecosystems

VPI10 Importation and Release of a New Biological Control Agent for Scotch Broom

In addition, two projects under other themes involved assessments of biological control of weeds:

CEN23 Optimizing Management of Core Mesquite Infestations across Australia

CEN24 Evaluating the Environmental Benefits from Managing WoNS in Natural Ecosystems

The research projects met issues and challenges frequently encountered in biocontrol projects in Australia over many years:

1. The need for a long term commitment in terms of both time and money to achieve a successful outcome
2. The value in supporting projects that have reached a critical stage but lack funding
3. Logistical and legal problems involved in working in and importing organisms from several countries, as well as limited taxonomic knowledge of endemic flora and fauna in those countries
4. Uncertainty in relation to host range of potential agents including genetic variation in target weed in native range
5. Unpredictability in terms of efficacy of an agent once it is released into a new environment
6. Unpredictability in terms of impact of successful biocontrol on either production or ecosystem recovery.

Lessons and Future Prospects

The outcomes of the funded projects confirmed that while biological control is a highly suitable and desirable method for weed control in Australia, it is not a "silver bullet" that is a complete answer to weed management. Unpredictability in efficacy of agents, once released, remains as a limitation.

Control of a weed does not, in itself, necessarily lead to increased production or its replacement by desirable plants. Biological control must be integrated with other weed management tactics for successful production and biodiversity outcomes.

There is an urgent need for improved monitoring and evaluation of biological control of weed programs. Follow-up monitoring after release of agents should be built into research program plans. Investment in these activities should be increased, although current short-term funding cycles do not encourage long-term evaluation.

This program has supported some projects that will clearly benefit from further funding to progress them towards completion (CEN8, CEN11, CEN12). With limited resources, future research efforts should target priority weeds where chances of success are considered relatively high.

Fifty two species (or groups, eg *Sida* spp.) have been the subject of some biological control research during the past decade. Several have been worked on for a much longer period (eg *Lantana camara*). While work on 13 different species has progressed to a point where active biological control agents have been released and redistributed from the initial release site, others remain at an early stage in the search for suitable control agents. Work on five of the 52 species has, for a variety of reasons, been placed on hold.

Clearly, research efforts and funding could be more focused on fewer target species. With this in mind, the 'Defeating the Weed Menace' R&D program commissioned a project to assist in prioritising future research into biological control of weeds: "Improved Targeting of Weed Biological Control Projects". A report on that project will be available on Land & Water Australia's website (**lwa.gov.au**) and will be widely disseminated to program and policy managers at national and state levels.

Tall invasive grasses and fire in a changing landscape

Samantha A. Setterfield, Natalie Rossiter-Rachor and Michael M Douglas, Charles Darwin University.

Australia's northern savannas cover approximately one-quarter of the continent, or approximately 2 million km^2. Australia's savannas are unique among the world's savannas because they have not experienced intensive use by humans and remain relatively intact. However, the integrity of these savannas is increasingly being threatened by a range of high biomass, invasive tropical grasses.

This includes grass species in NT, QLD and WA, such as:

- Gamba grass (*Andropogon gayanus*)
- Annual mission grass (*Pennisetum pedicellatum*)
- Perennial mission grass (*Pennisetum polystachion*)
- Grader grass (*Themeda quadrivalvis*)
- Guinea grass (*Megathyrsus maximus*)

These species were introduced primarily for assessment and/or use for pastoral production. They were selected for their persistence under harsh conditions, and for their higher growth rates and nutritional value compared to native grasses.

However, the characteristics that make these species successful pasture plants also make them successful weeds, and many of these introduced grass species have gone on to become problems outside of pastoral land.

Charles Darwin University researcher Dr Samantha Setterfield named Gamba grass as one of the most serious invasive grasses across the northern savannas.

"Gamba grass forms dense stands up to four metres tall, and almost completely replaces native vegetation communities," she said.

"Gamba now occurs from Cape York to the Kimberley. In the NT it covers an area of approximately 1.5 million hectares and is emerging as a significant threat for conservation, Aboriginal, pastoral, mining and defence land users".

Dr Natalie Rossiter-Rachor (Charles Darwin University) explained that one of the greatest issues of Gamba grass invasion is the impact on fire regimes (see Table 1). "Compared with native grasses, Gamba forms taller, denser stands, with fuel loads up to 25–30 tonnes/ha, compared to the typical native grass fuel loads of 2–4 tonnes/ha," explained Natalie. "The increased fuel loads of Gamba grass lead to substantial increases in fire intensity, with fires up to eight times greater than those fuelled by native grasses".

To test if high-intensity Gamba grass fires were leading to increased numbers of tree deaths, the CDU team combined historic and current aerial photography of areas in the Darwin rural area, together with field surveys. They found that in areas with Gamba grass, there was a 50% reduction in tree canopy cover over twelve years. This dramatic change in the structure of savanna vegetation demonstrates the serious risk that Gamba grass poses to northern Australia's savannas.

Hotter fires due to exotic grass invasion are changing fire management across northern Australia. Photo by Dr Samantha Setterfield

High intensity Gamba grass fires have been shown to have substantial impact on fire management practices and costs. Historically fires were low intensity native grass fires, which occurred in sparsely populated areas, and which could be managed using minimal fire fighting equipment. Gamba grass invasion has resulted in hotter fires occurring in residential areas, requiring helicopters and water bombing planes to effectively protect people's lives and properties. Further economic impacts of Gamba grass fires were evident when nine dwellings were destroyed in a single fire in the Darwin rural area in 2006. The cost of fires in areas invaded by exotic grasses will be significant as exotic grasses spread (see Table 2).

Dr Keith Ferdinands (NT Weed Management Branch) agreed that understanding the economic impact of exotic grass invasion and management is critical to developing cost-effective management strategies. The collaborative CDU/NT Government research team is continuing work on quantifying the social, environmental and management costs of invasive grasses to complete economic evaluations of different management approaches. This research will guide savanna weed managers in the fight against the grassy weed invasion.

For more information contact:

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Table 1. Comparison of typical fire behaviour of native grass and Gamba grass experimental fires (Source: *Rossiter et al.* 2003; *Rossiter et al.* 2008).

	Native grass Early Dry Season	Gamba grass Early Dry Season
Average Grass Fuel (t ha^{-1})	1.2–2.4	4.4–15.4
Rate of Spread (m s^{-1})	0.06–0.27	0.16–0.72
Fire Intensity (MWm^{-1})†	0.4–1.9	2.3–15.7
Scorch height (m)‡	4.2–10.1	13.04–21.4
Char Height (m)§	1.4–1.6	3–9.9

† *Fire intensity is the rate of heat release from a lineal segment of the fire perimeter*

‡ *Scorch height is the height that radiant heat has scorched the canopy leaves (and an indicator of flame height)*

§ *Char height is the height that radiant heat has blackened the canopy leaves (and an indicator of flame height)*

Table 2. Comparison of costs from (a) a single native grass fire and (b) a single Gamba grass in the Vernon fire management region, Northern Territory (~100 km Southeast of Darwin).

Type of fire and cost	Cost ($)
(a) Native grass fire	
Equipment Costs	
Vehicles × 2	
Staff Costs	
Bushfires NT brigade members × 4	
Total native grass fire costs	**1, 296**
(b) Gamba grass fire	
Equipment Costs	
Loader	
Water bombing plane	
Helicopter × 2	
Water Tanker	
Vehicles × 9	
Staff Costs	
Bushfires NT Staff × 3	
Bushfires NT brigade members × 4	
Bushfires NT fire ground staff × 3	
Total Gamba grass fire costs	**16, 702**

Dense stands of Gamba grass in the Northern Territory. The grass now poses a serious risk to savannah vegetation as it transforms key elements of the ecosystem. Photo by Dr Samantha Setterfield

Dense stands of Gamba grass in the Northern Territory. The grass now poses a serious risk to savannah vegetation as it transforms key elements of the ecosystem. Photo by Michael Douglas

Gamba grass invasion can lead to dramatic declines in tree canopy. Photo by Dr Samantha Setterfield

Gamba grass invasion leads to much hotter fires in the savannas. Photo by Dr Samantha Setterfield

Further Reading

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Environmental weeds of floodplains — causes, consequences and management

Matt Colloff and Kate Stokes, CSIRO Entomology

Environmental weeds are invasive plant species that have significant detrimental effects on natural ecosystems. Their adverse impacts may be on biodiversity, or entire ecosystems and processes like nutrient cycling, hydrology, fire and flood regimes. Collectively, these impacts can lead to a loss of ecosystem character and resilience, and lead to an undesirable ecological state which may require restoration. For these reasons, substantial resources are allocated for the control of environmental weeds.

Australian floodplains have been subject to massive changes in land and water use, river regulation and altered flow regimes. One of the purposes of this research was to predict if particular sites are more susceptible to weed invasion. Another was to determine whether a major ecological outcome of environmental water allocations would be an increase in weeds. Focussing on the River Murray, where flood events are now fewer, shallower, of shorter duration and more likely to occur during summer, we suspected that changes in flood disturbance might be a major factor responsible for compositional changes from native to exotic plant species.

To tackle these issues, we used site-scale monitoring data for 1993/4 and 2006/7 from Barmah Forest, and regional-scale data for the Murray floodplains. Exotic and native plant species were classified into functional groups based on their water requirements (terrestrial to aquatic), and plant data was compared with hydrological outputs from the River Murray Floodplain Inundation Model (RiM-FIM), a software tool that predicts flood variables from a range of river flow inputs.

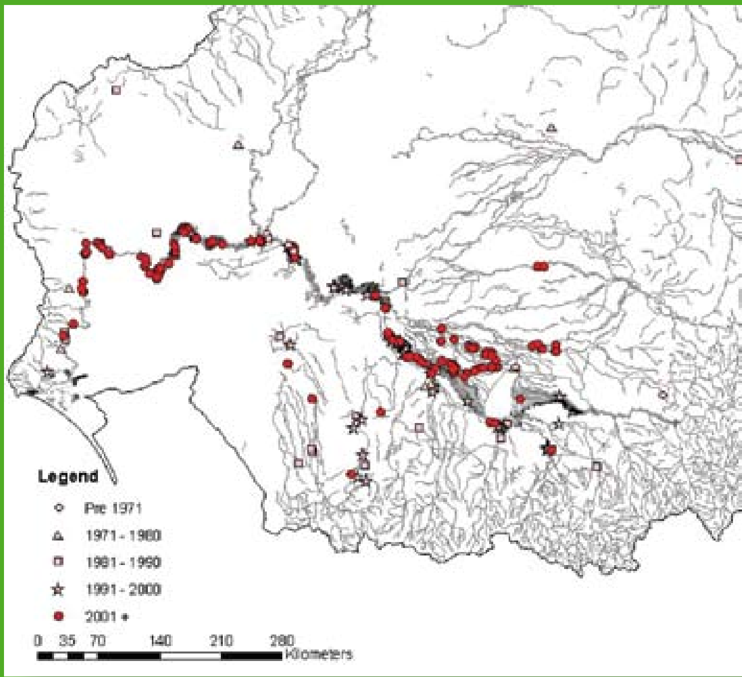
At the regional scale, the locations of plant functional groups were overlain against the relevant commence-to-fill values. Commence-to-fill is the volume of river flow required to flood that location. We found no clear relationships, implying the distribution of weeds is due to more complex variables than just commence-to-fill. Nor could we find evidence from hydrological data that some sites were more susceptible to weed invasion than others. The large dataset contains a fascinating source of information on the historical spread of certain weed species (see figure), and we are now undertaking more sophisticated analyses.

A drying wetland depression, a prime site for weed colonization at Barmah-Millewa forest. Photo Caroline Chong, CSIRO

Sagittaria graminea subsp. platyphylla at Barmah. Photo Caroline Chong, CSIRO

At the smaller scale, differences in plant composition were greatest during spring, with segregation of communities occurring along a gradient of water availability. Drier communities were associated with high cover of exotic species, which most commonly belonged to terrestrial functional groups. Between 1993/4 and 2006/7, the proportion of exotics in terrestrial groups increased, but in aquatic groups decreased. Native species richness and flood regime were significant predictors of exotic species richness. Native and exotic species richness were positively correlated, suggesting that at site-scale flood events are more important in regulating invasion processes, rather than competition from native plants. Flooding resets the ecological clock, and both natives and exotics benefit. The management implication is that environmental water allocations are predicted to reduce weeds, since fewer exotics occur in functional groups that require floods in order to germinate.

Map of the Murray floodplains showing the dispersal pattern of the weed Lippia (*Phyla canescens*) over time.



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Lippia (Phyla canescens). Photo Matt McDonald, University of New England

Understanding why weeds flourish in riparian zones

Dr Fiona Ede and Trevor Hunt, Department of Primary Industries Victoria

Riparian zones are the areas of land adjacent to rivers. Vegetation communities that develop in these zones are therefore influenced by both terrestrial and hydrological processes. Riparian corridors are often heavily invaded by weeds and weed control in these areas poses numerous management challenges.

A research project undertaken by the Department of Primary Industries Victoria in association with the CRC for Australian Weed Management and the Land & Water Australia Defeating the Weed Menace R&D program, assessed riparian vegetation communities at 35 sites where native species dominated the overstorey. This study found that on average, weeds made up almost 40% of the species present at sites, with exotic species outnumbering native species at seven sites. At half the study sites, the vegetation cover of the exotic species was greater than the cover of the native species.

So why are riparian zones so weed-prone? Often riparian zones form narrow, linear corridors in the landscape, with high edge to area ratios. The long edges mean that there are multiple entry points for weeds, from both the landward and riverward sides. Weeds can move into riparian vegetation from adjacent land, particularly where land clearing or other human activities have increased the abundance of weeds. Seeds and viable fragments of many weeds can be transported downstream, especially during flood events. Floods also create ideal recruitment opportunities of bare ground for many weeds through the erosion and subsequent deposition of sediment along the river corridor. Weed growth is also promoted by favourable environmental conditions in riparian zones, particularly the higher soil moisture and nutrient levels found in these areas in comparison to those in adjacent areas.

All of these characteristics mean that often riparian communities contain multiple weed species, ranging from herbs and grasses through to shrubs and trees. Weed management in such areas is complex, and further complicated by limitations on control options. Chemical control options in riparian zones are restricted to those herbicides which can be safely used around waterways, while physical control may be feasible in some sites but not others where access is difficult. Biological control can be effective on individual weed species, but in sites with multiple weed species, is of limited use.

Developing effective weed management strategies for a site requires clarification of the overall aims of the management program for the site and the role of weed management within that program. It is important to recognise that in some situations it is not feasible to completely eradicate weeds. The desired outcome of management should be a riparian zone dominated by native plants, that fulfils important ecological, hydrological and social functions.

Weed management in riparian areas can be complex, especially where multiple weed species occur in close proximity to native species as with the blackberry, caper spurge, hemlock and blue periwinkle at this site on the Tambo River, Victoria. Photo by Trevor Hunt, DPI Victoria.

Understanding the sources and dispersal patterns of weeds at the site is important as well, as weed management outside the site may be required to prevent re-invasion. In recognising that riparian zones are highly invasible, post-weed control strategies should be adopted to ensure that areas are cleared not re-invaded. Replanting or seeding with native species may be necessary to prevent re-establishment of weeds.

Although effective weed management in riparian zones can be complex and may take many years to achieve, it is possible and can result in significant benefits to both the biodiversity of the riparian zone and to the river itself.

Above: Dense infestations of blackberry can impact on ecological and recreational values of riparian zones. Photo by Trevor Hunt, DPI Victoria.

Above: Rivers can act as conduits for weed propagules moving through the environment, with stem fragments of crack willow particularly well adapted to water dispersal. Photo by Fiona Ede, DPI Victoria.

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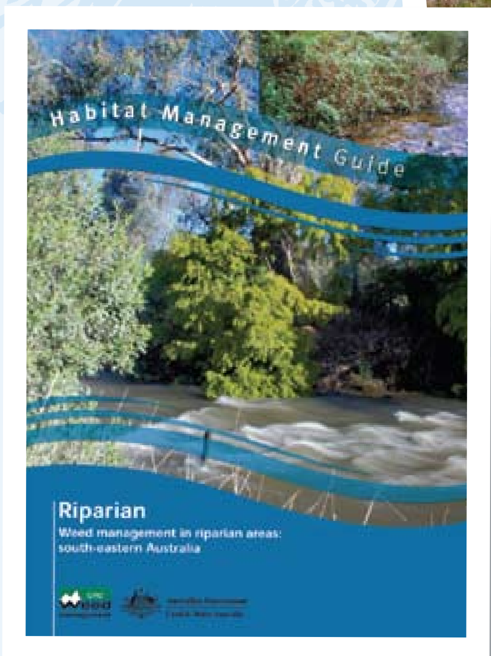

The Riparian Guidelines can be found on the CRC for Australian Weed Management website: ***http://www.weedscrc.org.au/publications/weed_man_guides.html#habitat***

Balancing competing interests of plants that have commercial value and weed potential

Margaret Friedel, CSIRO Sustainable Ecosystems, Susan Kinnear and Bob Miles, Institute for Sustainable Regional Development Central Queensland University

Some introduced pasture plants have been very successful at improving Australian livestock production. For example, olive hymenachne (*Hymenachne amplexicaulis*) is used as a ponded pasture species in tropical Australia and buffel grass (*Cenchrus ciliaris*) is an important grazing resource in arid and semi-arid regions. Buffel grass can also help to control erosion.

Unfortunately, the ease with which these plants spread beyond where they are planted means that both are now major environmental weeds. Olive hymenachne is a declared weed, but remains largely uncontrolled, while policies addressing the management of buffel grass have yet to be developed.

Part of the challenge for managing these weeds is to understand people's perceptions of them, including the benefits and costs of each species, and therefore understand what can be done to encourage better management.

CSIRO researchers found that a broad spectrum of stakeholders from north Queensland, north-east South Australia, central Australia and the Pilbara shared similar views about the improved livestock production and erosion control benefits of buffel grass, despite the contrasting environmental conditions. Perceptions of costs were very different between institutional focus groups and individual landholders, and amongst regions. The costs recognised by institutional groups depended on which region they represented. The most frequently cited costs were monocultures, fire risk, biodiversity impacts and costs of control. Producers generally thought that the main cost of buffel grass was the expense of seeding and establishment.

Pastoral and conservation institutions broadly agreed on management objectives for environmental reserves and for pastoral lands of low conservation value, and agreed on management tools and strategies. The contentious issue for institutions within and between regions was deciding on management objectives for pastoral land of high conservation value. Amongst individual landholders, few aimed to keep buffel grass out of their own areas with high conservation value, but over 40% placed a high value on managing buffel grass within reserves. There seemed to be sufficient common ground for progress towards better management to be possible.

CQUniversity researchers identified significant disagreement between landholders about the impacts of olive hymenachne on production. Some viewed the plant as an important resource for grazing cattle, while others saw it as a weed. There was also disagreement about the effectiveness of control strategies. Like landholders, policy makers also appeared to share varying attitudes with respect to control efforts for olive hymenachne.

Cattle grazing on buffel grass pasture. Photo by Paul Jones, Queensland DPI.

Nevertheless, CQUniversity researchers identified several positive opportunities for improvement. For example, a number of information gaps and evaluation mechanisms could be addressed. As the costs of control were generally low, targeted incentives and encouragement mechanisms could improve rates of control activity. There was also potential for a renewed focus on managing infestations in small catchments and isolated outbreaks, and in some situations for the use of regulatory mechanisms to ensure a minimum level of compliance.

In order to achieve sustainable management of both species for production and conservation, a more coordinated approach is needed. This approach should address knowledge gaps, awareness, network mechanisms and the development of regionally appropriate controls, incentives and policies.

Actions should include:

- better documentation of local/catchment/regional management options and outcomes, including benefits and costs
- engaging landholders in identifying how different strategies may impact on participation, cooperation and cost-sharing arrangements
- better communication amongst stakeholders and recognition of existing networks
- prioritising protection of high value environmental assets
- engaging stakeholders in identifying regulatory and institutional structures and support programs to allow for different local and regional needs.

Above left: CQUniversity researches in the field. Photo by Leo Duivenvoorden.

Above right: Hymenachne shooting from stranded debris in Ramsay Creek. Photo by Wayne Houston

Differences exist amongst interest groups on the value and impact of plants of commercial value and weed potential like buffel grass and olive hymenachne. Therefore, there is an urgent need to consider what policy and institutional settings are required for the effective management and use of these plants.

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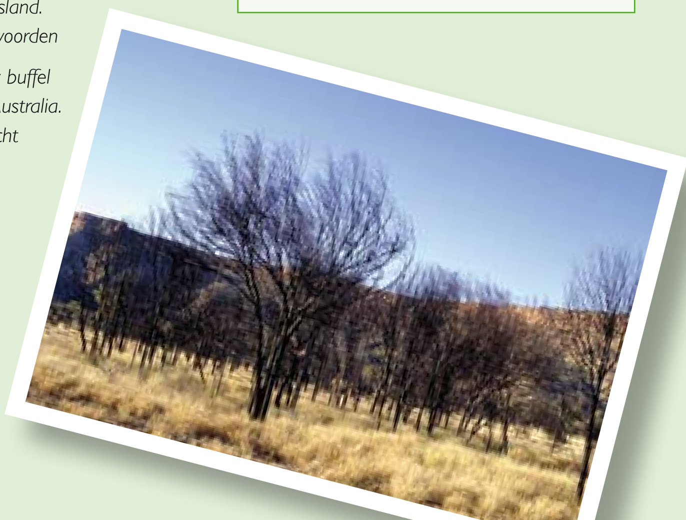
Left: Hymenachne in Maryvale Creek, central Queensland. Photo by Leo Duivenvoorden



Right: Mulga killed by buffel grass fire in Central Australia. Photo by Dave Albrecht

Where will Australia's weeds move to? Climate change impacts on weeds

Article prepared from a research project led by Dr John Scott, CSIRO Entomology

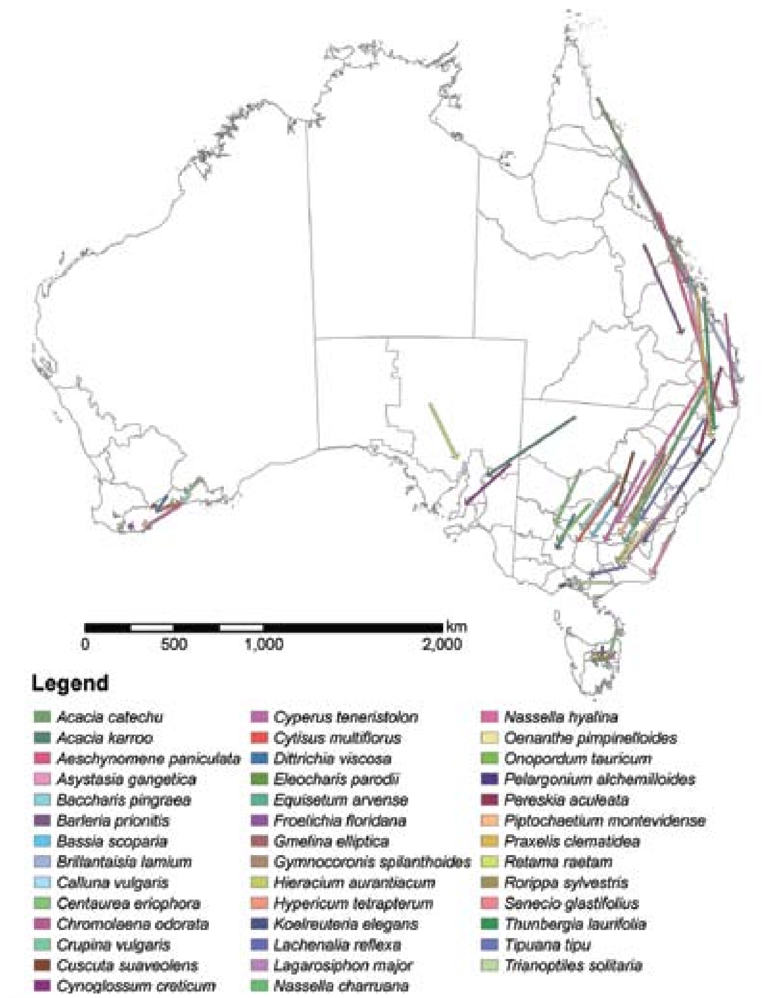
It is now confidently predicted that our climate will change in the coming decades. As a consequence, some weeds will have greater potential to spread in the future, whereas others might become less damaging than they are today.

Of particular interest are those weeds that are currently described as either 'sleeper' or 'alert' weeds — weeds that might scarcely be noticed at present. Sleeper weeds are those introduced plants that are at present limited in their distribution but have the potential to become significant weeds impacting on Australian agriculture. A second group of introduced species, at present in their early stages of establishment but with the potential to become a significant threat to biodiversity, are identified as environmentally alert species.

A project led by CSIRO's Dr John Scott has combined modeling of plant responses to rainfall and temperature with recognised climate change models to address the question: "which of these species requires greatest attention as the climate changes?".

Using CLIMEX, the leading program used to model species distributions, and combining it with OzClim which is used to model climate change scenarios, the project has studied the potential distribution of the 41 sleeper and alert species listed nationally across Australia see figure 1.

Figure 1: Displacement predicted for the most likely regions for establishment of alert and sleeper weed species.



Karroo Weed. CRC photo

By adopting a regional approach to climate change modeling and building in a range of stress factors, the project team has developed a climate change weed risk map of NRM regions across Australia. Figure 2 shows the number of sleeper and alert weed species with a high Ecoclimatic Index. The Ecoclimatic Index measures the suitability of plants for survival under climatic conditions modeled using different climate change predictions.

As plant species migrate south under changed climatic conditions, the results clearly indicate that the south-east and to a lesser extent the south-west regions of Australia are most at risk from the sleeper and alert weeds.

Scott and his colleagues predict that the greatest shifts in distribution (of over 1000km) will be for species currently found in the wet tropical regions, while south coast species will move a much shorter distance because they will run out of landmass to move into.

While some alert and sleeper species are predicted to present little threat as climate change impacts take hold, others such as *Acacia karroo* (Karroo thorn), *Retama raetam* (White weeping broom) and *Equisetum arvense* (Common horsetail) are predicted to become major problems unless well managed.

The results of this research will be further refined and a number of policy and management recommendations are being developed.

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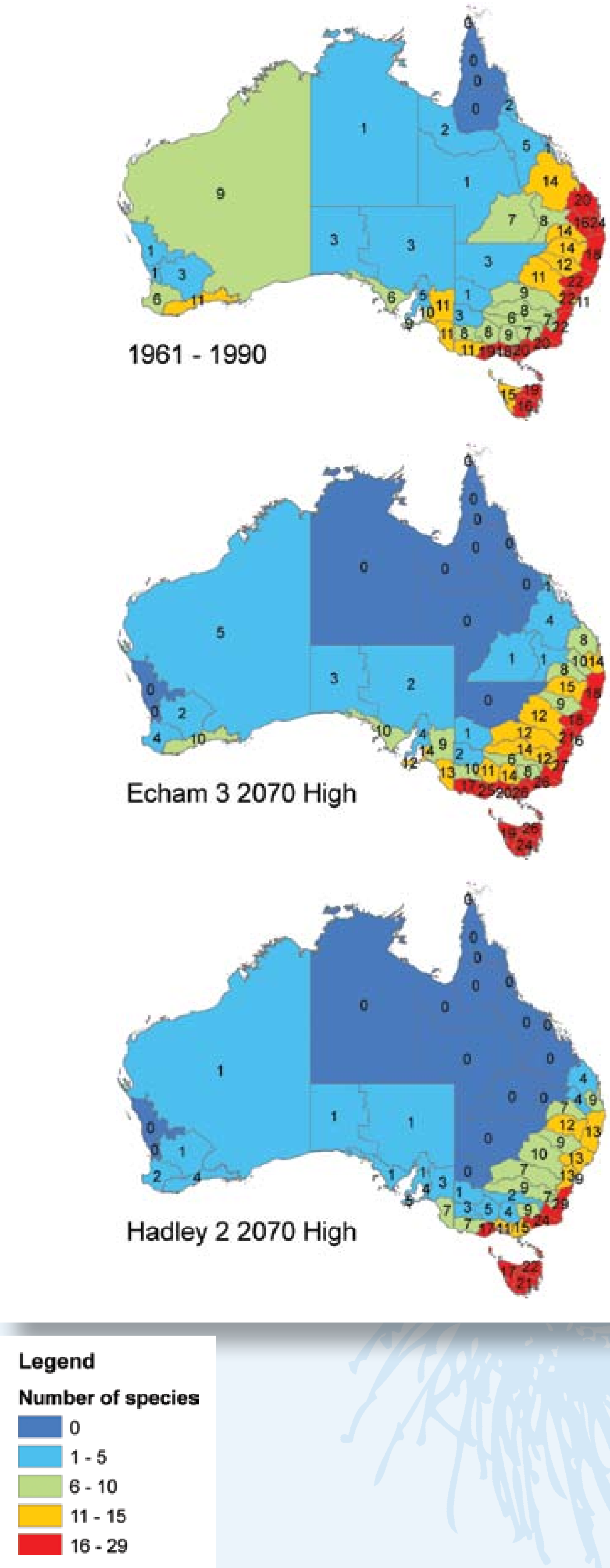
Figure 2. Number of species with maximum Ecoclimatic Index over 90 in NRM region



Undertaking weed biological control research: processes, protocols, challenges and benefits

Dr Louise Morin, CSIRO Entomology

Australian scientists have been at the forefront of weed biological control (biocontrol) since the successful control of prickly pear with the *Cactoblastis* caterpillar, introduced in the 1920s. A recent series of benefit-cost analyses revealed an outstanding overall benefit-cost ratio of 23:1 for weed biocontrol programs in Australia.

The classical approach of biocontrol involves the deliberate introduction of one or more natural enemies of the target weed into the environment where the weed has naturalised and become troublesome. The aim is for populations of these biocontrol agents (generally insect herbivores or pathogens) to establish permanently, become widespread and thrive in the new location, and as a result reduce the weed's economic and environmental impact.

There is always a risk, however slight, of unforeseen consequences from every new introduction of exotic organisms. Biocontrol programs aim to choose the most efficacious candidates for further testing in order to reduce the number of introductions and costs, and improve the success rate. It can be difficult however, to predict 1) whether a prospective agent will develop and maintain sufficiently large populations in the new location, because the biotic environment is different from its native range, and 2) the level of damage the agent will cause to the target weed in the new location and whether it will achieve the desired weed management outcomes.

Once potential agents have been selected and prioritised, host-specificity testing determines the potential range of plants which could be attacked by the agent in the new location. This testing is tailored to the particular agent and concentrates on plants closely related to the target weed, focusing on plants which occur in the same climatic and ecological zone as the weed. Experiments are undertaken in the field, in laboratories overseas and/or in containment facilities in Australia.

Results from host-specificity tests are considered by the Australian Government quarantine and environment protection agencies before approval for introduction is granted. The best possible approaches are then used for mass-rearing and releases to ensure that the agent has the maximum chance of successfully establishing. For example, site characteristics, weather conditions and the number of individuals released can play a major role in agent establishment. Once field populations of the agent have built up at nursery sites, they can be harvested for distribution to other sites. This stage of a biocontrol program often involves land managers and community groups.

Searching for natural enemies of Cabomba in its native range. Photo: Ricardo Segura, CSIRO Entomology

Reduction of bridal creeper density following biological control at Yanchep National Park, Western Australia. Photo: Perth-based CSIRO Entomology staff

Unfortunately, the evaluation phase of biocontrol programs is often neglected due to inadequate resources and funding. Evaluating the agent's impact on the weed is vital 1) to help fine-tune control of the target weed and make it more effective, either by introducing additional agents or combining with other control techniques, and 2) to demonstrate at the national level the value of investment in biocontrol program research. Impact assessments aim to determine how the agent has affected the target weed, taking into consideration the underlying spatio-temporal variability of the system and abiotic conditions. This, in turn, may have benefited other plant communities and ecosystems, as well as society and the economy at large. Unfortunately, the evaluation phase of biocontrol programs is often neglected due to inadequate resources and funding.

More detailed information on the core aspects of weed biocontrol programs can be found in two Best Practice Guides and four Factsheets recently produced by the Cooperative Research Centre for Australian Weed Management (available at **www.weedscrc.org.au/publications**).

The Land & Water Australia Defeating the Weed Menace R&D program supported several biological control programs from 2006 to 2008.

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Assessing establishment of the leaf-rolling moth (Tortrix sp.) on bitou bush in New South Wales. Photo: CSIRO Entomology

Close-up of an adult leaf-feeding beetle (Zygogramma bicolorata) feeding on parthenium weed. Photo: K. Dhileepan, Queensland Department of Primary Industries and Fisheries

The rust fungus (Puccinia myrsiphylli) released in 2000 for the biocontrol of bridal creeper. Photo: CSIRO Entomology

Witches' broom caused by the rust fungus Endophyllum osteospermi on a boneseed plant. Photo: Dr Louise Morin, CSIRO Entomology

Evaluating the impact of a biological control agent on bridal creeper and the response of associated vegetation to a reduction in the weed population. Photo: Peter Turner, CSIRO Entomology/University of Western Australia

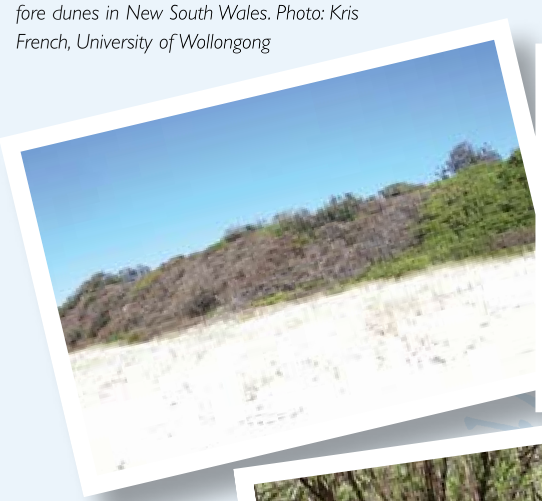
Has controlling Weeds of National Significance benefited natural ecosystems?

Dr Louise Morin, CSIRO Entomology

Weeds pose a significant threat to natural ecosystems in Australia and consequently large amounts of resources are spent each year to control them. A desktop analysis, consisting of a literature review and survey of land managers, was recently undertaken by a consortium of research providers (CSIRO Entomology, NSW Department of Environment and Climate Change, University of Wollongong, SA Department of Water, Land and Biodiversity Conservation) to determine if native communities and ecosystem processes recover following weed control. To limit its scope, the analysis concentrated on the 20 Weeds of National Significance (WoNS), which are Australia's priority weeds due to their high economic and environmental impacts and have been the focus of much research and on-ground management.

A review of the relevant scientific literature identified 94 published papers on the management of WoNS in natural ecosystems in Australia. It revealed that the response of plant communities following WoNS control is not often monitored. Of the 17 studies that did incorporate some form of plant communities monitoring, it was found that native plant species did not necessarily readily recover following WoNS control, and in many cases the WoNS was replaced by other weed species. There was also a distinct lack of information (only three studies) on the response of animal and microbial communities and ecosystem processes following the removal of a WoNS species.

A total of 168 replies were received in response to a land manager survey, with more than 50% of control programs focusing on four WoNS: blackberry, bitou bush/ boneseed, bridal creeper and willows. Results from the survey revealed that although biodiversity conservation was the aim of 76% of programs, monitoring efforts focused primarily on the response of the target WoNS to the control actions and to a much lesser extent on the response of other plant species. The respondents who monitored changes after control of a WoNS reported that it was replaced by bare ground (8%), by weed species only (including self) (13%), by native plants only (25%) and by a combination of native and weed species (44%). Ten percent of respondents did not know the replacement species.



Small scale herbicide control of bitou bush on fore dunes in New South Wales. Photo: Kris French, University of Wollongong

The native plant species Pimelea spicata threatened by bridal creeper. Photo: Tony Willis, CSIRO Plant Industry.

This rare white Coast Swainson Pea (Swainsona lessertiifolia) is flowering abundantly in restored coastal Banksia woodland after a 5-year management program targeting bridal creeper. Photo: Mae Adams, Venus Bay, Victoria.

Riparian area invaded by willows and blackberry. Photo: Dr Louise Morin, CSIRO Entomology.

Cape ivy replacing bridal creeper following successful biological control at Broulee, New South Wales. Photo: Louise Morin, CSIRO Entomology

The research team's findings highlight that control programs for WoNS and other weed species in natural ecosystems should put greater emphasis on monitoring the response of native species to the reduction or removal of the target weeds. Monitoring is essential to identify if the control methods used damage native plants and to provide information to decide whether additional interventions are required to assist native plant communities to recover. Microbial and animal communities, and ecosystem processes should also be monitored to get a more complete assessment of how natural ecosystems respond to weed control, but it is unrealistic to expect on-ground land managers to implement this type of detailed monitoring. Such monitoring is better left for trained researchers to undertake at representative sites to address current knowledge gaps.

The findings also suggest that a whole-system approach, integrating weed management programs with other actions may be essential to assist the recovery of native communities, restore the structure and function of ecosystems and protect against future weed invasion. Long-term monitoring is crucial to evaluate the effectiveness of this integrated approach for restoring an ecosystem.

The project was conducted by Drs Adele Reid and Louise Morin (CSIRO Entomology), Dr Paul Downey (NSW Department of Environment and Climate Change), Associate Prof Kris French (University of Wollongong) and Dr John Virtue (SA Department of Water, Land and Biodiversity Conservation), and was supported by the Defeating the Weed Menace R&D program, which is managed by Land & Water Australia.

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Setting up permanent transects in a blackberry infestation to facilitate monitoring following implementation of control program. Photo: Dr Louise Morin, CSIRO Entomology

The Environmental Weed Management Action Tool (EWeedMAT) — a new tool for regional environmental weed planning

Melissa Herpich and Dr Andrea Lindsay, South Australian Department for Environment and Heritage

Environmental weeds, those species of plant which can successfully invade and reproduce in bushland areas, are a recognised threat to the biodiversity of remnant vegetation across Australia.

Growing recognition of the threat has seen the proliferation, in recent years, of a multitude of weed plans and strategies across all levels and scales of government and natural resource management planning. While these are designed to guide efforts against weeds in a strategic manner, most plans fail to include practical considerations, such as where the weeds are, or are at a scale which fails to influence on-ground management.

The move towards regional Natural Resource Management (NRM) planning has created the opportunity for environmental weeds to be tackled in a more effective way. It has created easy avenues for local knowledge on environmental weeds and their spread to be incorporated into planning processes and allows environmental weed management to be integrated with complementary activities such as the restoration, management and monitoring of natural areas. The existing mechanism for disbursement of NRM funds through the regions is also a logical way to direct funds towards weed management.

Bridal Creeper, Asparagus asparogoides. The Western Cape form of Bridal Creeper, shown here, is found only in South Australia and is resistant to the bridal creeper rust. Photo by L. Geelen

In recognition of the advantages of regional environmental weed action, the Department of Environment and Heritage, in the South East Natural Resources Management Region of South Australia, has developed a planning tool to help prioritise on ground environmental weed actions at the regional scale. The result of this process is a model called the *Environmental Weed Management Action Tool* (EWeedMAT). This 'Tool' was designed to be practical, providing regionally specific support for decision making for investment of weed management funds in on-ground works.

Through the process of development EWeedMAT has been tested and refined in two NRM regions.

A risk management approach was used as the basis of the 'Tool'. This produces an **Environmental Weed Management Priority Index** for each substantial patch of remnant vegetation within a region based on its biodiversity values and the threat of weeds to biodiversity. The larger the *Environmental Weed Management Priority Index* the higher the priority of vegetation patches for weed management.

The biological attributes identified in EWeedMAT as important for the targeted NRM regions include well recognised indicators of remnant vegetation health and significance, specifically the presence of threatened ecological communities and species and measures of vegetation diversity. Physical values of each patch which affect invasion risk (shape, size and management factors) are also included in the calculation.

The weed threat values incorporated into the 'tool' include a numerical representation of the invasiveness and potential impact of major weed species present. These figures are combined with an infestation score representing the infestation level for each weed found in a patch of bush. It should be noted that the 'tool' incorporates measures of actual weed infestation at each patch of remnant vegetation considered, that is, it is *not* predictive.

EWeedMAT has proven to be an effective tool for encouraging strategic management of weeds across the landscape in the regions to which it has been applied. It has broad application to the temperate regions of Australia and could easily be adapted to incorporate other threats, or values relevant to management of natural areas. The tool is relatively simple to use, it runs through a spreadsheet rather than specialised software and can easily be adapted.

The Environmental Weed Management Action Tool was developed and published by the Department for Environment and Heritage (SA) and the South East NRM Board using funding from the Australian government. Results are now being used in the two NRM regions in South Australia where it was developed and tested.

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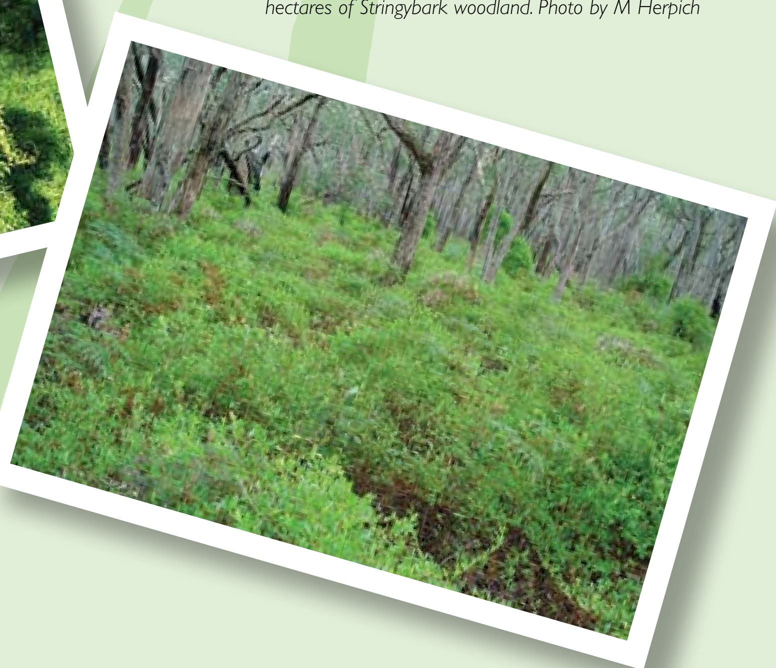
Bridal creeper in understorey. Photo by A Hay

Native Bluebell Creeper, (Billardiera heterophylla) is a native of Western Australia but outside its natural range becomes a significant weed of bushland. This infestation in South Australia has completely smothered the understorey of hundreds of hectares of Stringybark woodland. Photo by M Herpich



Detecting pine wildlings using remote sensing technology

Melissa Herpich, South Australian Department for Environment and Heritage

In the Green Triangle Region, which straddles the southern South Australian/Victorian border, *Pinus radiata* is a significant commercial plantation species. The very characteristics that make it a useful plantation species also make it a very effective bushland invader. It is a generally hardy plant, which establishes readily under competition conditions, grows quickly, thrives in a range of habitats and produces large amounts of wind distributed seed.

In recognition of this emerging issue, the South Australian Department for Environment and Heritage, together with representatives of the local plantation industry and other agencies, set out to determine what the true distribution of wild radiata pines (called wildlings) was across the area.

As pine trees tend to be emergent through the canopy in the low woodlands that characterise the area, there was a good likelihood that the easiest way to detect the trees was to use remote sensing and Geographic Information System (GIS) technologies. These make use of satellite imagery to detect pine trees by identifying differences in reflectance values between pixels in an image.

This proved harder to establish than the project team originally predicted. While the human eye can readily detect the difference in colours between pine trees and the other vegetation they are growing amongst, it is much harder for a computer to do the same. Fortunately a solution presented itself in the form of a CSIRO developed program which utilises crown delineation technology.

This technology classifies groups of pixels as crowns rather than simply classifying each pixel based on its colour. When applying this technology to specific sites in the project area, density maps of pine wildlings were produced. Figure 1 shows different classifications of pines based on the degree of certainty associated with their classification as pines. Therefore, the dots shown in green are classified as *pines*, while the yellow are *mostly pines* and the red *mostly mixed*. These classifications recognise the different types of errors generated by the program as pines grow mixed with other vegetation which obscures the crowns.

The site shown in figure 1 is bushland (State forest) which is bordered by old, established pine plantation on the left hand side (whited out). Interestingly the pine invasion detected, which radiates from the left to the right, reflects expected dispersal of seed from the oldest part of the plantation area.

It is acknowledged that using remote sensing for this type of application is fraught with error. The methodology trialled in this project consistently produces both positive errors (trees that are not pines labelled as pines) and negative errors (pine trees not detected) and the range of errors varies between vegetation types. What we do know is that the methodology, while missing some trees and attributing some trees incorrectly, consistently underestimates the number of emergent pine trees in an area.

This is not necessarily a problem, as the aim of the project has always been to give an idea of the scale of the issue in the region. Underestimating in this context simply means that the results produced must be recognised as being conservative in all cases. Because trees that cannot be seen by the satellite will not be detected, the results will inevitably be conservative estimates.

Large pine wildings growing in bushland, the spoil in the front of the photo is from recently harvested pine plantation. Photo by Melissa Herpich.

What is plain is that, as the map shows, there is a large issue looming in the Green Triangle Region, and perhaps in all areas where pines are grown near bushland.

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Figure 1. Rennick Map — pine wildlings detected in bushland adjacent to pine plantation (whited out)

Understanding weeds: sharing our knowledge across the wider landscape

Judy Lambert, National Weeds R&D Coordinator, Land & Water Australia

Both common sense and a considerable body of social sciences and rural extension literature tell us that if good science is to inform decision making, then intended end-users of that science not only need to know about it, but also understand its worth.

Judy Lambert

As a research broker, Land & Water Australia has for many years placed emphasis on 'knowledge for adoption' — getting the best possible uptake of the knowledge generated by the research projects it commissions.

Faced with the role of coordinating the Australian Government's National Weeds Research and Development (R&D) program, then known as Defeating the Weed Menace, I began by familiarising myself with all of the key players, their roles and responsibilities, and the relationships between them. I wanted a good idea of 'who's who' in weeds across Australia. The result was a 'spaghetti diagram' of almost frightening complexity.

Then there was the added complexity of where weeds fit into the broader picture of managing natural resources across rural production landscapes, rapidly changing peri-urban areas and significant remnants of urban bushland.

Involving all of these key players and getting research projects completed in the two-year timeframe that was available at the beginning of the program presented a real challenge.

One of the important steps in developing knowledge for adoption is to ensure that research projects are designed from the outset with the needs of potential end-users in mind. The project management cycle in Figure 1 shows multiple points of entry where project outcomes can be influenced to create better adoption potential.

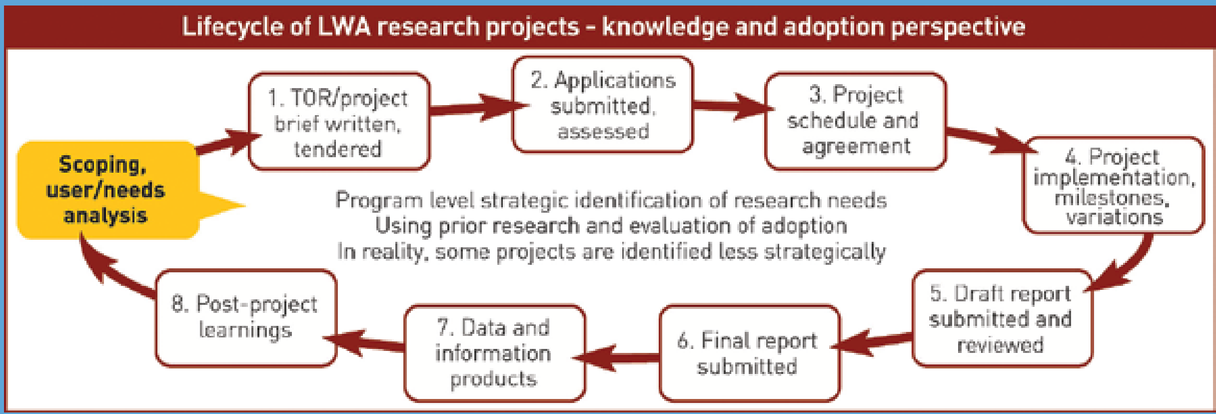
Throughout the relatively short life of the National Weeds R&D program, Land & Water Australia sought to ensure that all researchers took account of the knowledge potential of their project and considered pathways for adoption.

Researchers were asked to provide a Knowledge & Adoption plan as part of their initial reporting milestone. The plan identified target audiences, be they landholders, catchment management or other regional groups, policy makers in the states and territories or at national level, or other researchers. Along with identifying the target audience for each research project, research teams were asked to think about the most appropriate ways of communicating with them. Reporting on knowledge for adoption activities formed an integral part of each project milestone report.

As the projects moved towards their expected conclusion in June 2008, representatives from each of the project groups came together at a Knowledge Assimilation workshop to share their research and to identify opportunities for promoting the outcomes of their work.

Researchers identified one or more knowledge products. Peer reviewed scientific papers, which are important both in scientists' careers and in advancing scientific knowledge were understandably an important focus. But so were fact sheets, management guidelines, planning tools and policy

Figure 1



papers. In one instance, a video demonstrating some innovative spectral analysis technology and its application to weeds detection was produced.

Perhaps even more importantly, the research teams participating in the Knowledge Assimilation workshop identified mutual benefits of bringing together findings from sometimes quite diverse projects.

Researchers addressing weed management in floodplain and riparian areas combined with others examining the impacts of past and present land uses on soil nutrients and weed spread. This collaboration resulted in the production of a discussion paper on how these and other issues come together in managing the landscape as a whole, and where weeds sit in that management framework.

The relative risks associated with different pathways by which weeds spread, and the likely impacts of climate change on that spread were also synthesized as knowledge arising from multiple projects.

Additionally, emerging technologies in imaging and spectral analysis, when combined with the use of small unmanned aircraft or mini-helicopters (designed for other uses), have much to offer in detecting weed invasion in otherwise relatively inaccessible areas.

Researchers often have to compete with their peers for funding, and so sharing of information beyond publication in scientific journals is not common. As coordinator of the National Weeds R&D program it is pleasing to see research teams respond so positively to the catalysts provided and increase sharing of new knowledge in ways that should benefit multiple stakeholders.

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Urbanisation and aquatic weeds

Louise Lawrence and Dr Lauren Quinn, CSIRO Entomology

As Australian cities expand, adjacent (peri-urban) landscapes can be altered by environmental pressures typical of urban land use. In particular, peri-urban waterways can experience changes in disturbance frequency and intensity, increased input of nutrient pollutants, and reduction in riverbank (riparian) forest cover. These changes create ideal conditions for aquatic weed species, putting these waterways at risk.

When aquatic weeds establish in waterways they can cause a number of environmental problems. Certain aquatic weeds are known to negatively affect habitat for native fauna, such as turtles, fish and platypus. Floating and emergent species can cause water loss from catchments through high rates of transpiration, and both floating and submerged growth forms are known to impede recreational activities like swimming, fishing, and boating. Because stream systems are connected, it is important that weed invasions are identified and managed before they can spread downstream.

CSIRO researchers, Drs Lauren Quinn, Shon Schooler, and Rieks van Klinken, studied the impacts of peri-urban developments on the distribution of aquatic weeds in Australia. Specifically, they quantified:

- the size of the current aquatic weed problem in Australia (species, location, and abundance)
- whether aquatic weed invasions are the result of changes in the environment, such as increased nutrient loads, changes to water flows, or riparian canopy structure.

The team generated a ranked list of the top 24 aquatic weed species invading peri-urban waterways, based on current distribution and abundance. The most widespread species included alligator weed (*Alternanthera philoxeroides*), dense water weed (*Egeria densa*), parrot's feather (*Myriophyllum aquaticum*), salvinia (*Salvinia molesta*), and water hyacinth (*Eichhornia crassipes*). The research team cautioned that species currently considered uncommon or rare, such as oxygen weed (*Lagarosiphon major*) and water lettuce (*Pistia stratiotes*), should not be discounted as benign. Management should be tailored to the relative distribution of a weed. For example, biocontrol may be the best choice for the elimination of widespread species, while for rarer species focused early-detection programs may be the most appropriate first step.

One of the highly-ranked weeds,carolina fanwort (*Cabomba caroliniana*), was the subject of two controlled experiments. The first showed an immediate growth response in nitrogen-enriched environments, which has implications for farm dams where fertiliser runoff enhances the risk of invasion by aquatic weeds. These dams could be sources of infestation for nearby river systems. Regulation of nitrogenous runoff, particularly in peri-urban agricultural areas, may prevent the rapid spread of aquatic weeds. The second study investigated the effect of shade on controlling *Cabomba. caroliniana*, and revealed that the growth rate in deep shade was much slower than in full sun. This result suggests that restorating riparian canopies, thus increasing shade may help to combat the invasion of this species.

Egeria densa (dense water weed) and Salvinia molesta (giant salvinia) on an oar in a dam near Brisbane. These aquatic weeds impede recreational activities.

Field surveys of waterways near five Australian cities confirmed that greater numbers of aquatic weed species were found in urban areas than in undisturbed locations higher up in the catchments. Peri-urban sites hosted an intermediate number of weed species compared with the other types of land use, but the weed species that were present were capable of aggressively competing with native species. Compared with urban and undisturbed sites, native biodiversity was greatest in peri-urban sites. These results confirm that peri-urban sites represent a transition zone between heavily impacted urban locations and undisturbed headwaters, and suggest that these sites should be targeted for management to protect native aquatic plant biodiversity.

In addition to describing the abundance of native and weed species in three land use types per catchment, the team attempted to correlate presence of weed species with water quality and other environmental parameters. In their analysis, the only significant predictors of aquatic weed presence were intensive (urban) land use and reduced canopy cover.

As a result of their research, the group made two recommendations:

- council weeds officers, catchment care volunteers, and other land managers should focus their early-detection and control efforts on peri-urban and urban land use areas
- riparian forests should be restored to reduce light availability and buffer nutrient inputs, resulting in sustained reduction of aquatic weed populations.

The project was funded by the Australian Government's Defeating the Weed Menace R&D program, managed by Land & Water Australia on behalf of the Department of Agriculture, Fisheries and Forestry and the Department of the Environment, Water, Heritage and the Arts.

Above: CSIRO researcher Dr Lauren Quinn counts aquatic weed species in a dam near Brisbane.

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Below: A peri-urban sampling location near Melbourne. Many peri-urban sites have experienced similar reductions in riparian forest cover, which can result in proliferation of both aquatic and terrestrial invasive plant species.

An example of an urban sampling location. Many urban waterways have been heavily modified (in this case, channelised for stormwater drainage), which can result in optimal conditions for aquatic weed invasions.

The soil seed bank of woodland remnants: a resource for restoration in weed infested woodlands?

Elizabeth Lindsay, CSIRO Entomology

Many woodland remnants today are found on private property surrounded by productive agricultural land. Most have been disturbed by landscape fragmentation, livestock grazing, weed invasion, nutrient enrichment or soil compaction. Research has been conducted on small patches of woodland within agricultural landscapes for three years. As part of this work the soil seed bank of eleven woodland sites in the Boorowa and Young districts were investigated. This district contains both our most botanically diverse and our most disturbed field sites, which could be the most challenging to restore. The remnants are located on private properties and travelling stock reserves with a long history of livestock grazing; five of the sites have had livestock excluded for up to twelve years.

For many understorey plants, little is known about their seed dispersal or how long the seeds will survive in the soil seed bank. Previous seed bank work in other parts of Australia has identified numerous species that were not present in the standing vegetation. This research was interested to find out if there were native plant seeds in the soil seed bank which were not present in the standing vegetation, and if there were native plant species which were rare as adults but with a large seed reserve in the soil. The research also wanted to see if the soil seed bank changes with land use intensity and the current grazing regime.

Soil samples were collected in January 2008 and placed in seedling trays in a glasshouse. They were watered daily. Each new seedling that emerged was given a morphospecies code and then grown up in another glasshouse, or in the seedling tray if delicate, until it could be identified. Additional species are still germinating with the addition of water, and if time permits additional germination treatments will be attempted.

A viable soil seed bank was present at all sites, and it was much larger than expected. After eleven months of germination, over 24000 monocotyledonous and 7000 dicotyledonous individuals have emerged from $0.43m^3$ of soil and more seedlings are continuing to emerge. There is much greater diversity in the seed bank than was detected in the vegetation surveys. At present there are around 80 monocot morphospecies and 110 dicot morphospecies, though some of these morphospecies are expected to turn out to be the same species.

Seed trays filled with seedlings germinated from soil collected from woodland remnants in the glasshouse.

Exotics grasses (e.g. rye) and forbs (e.g. Paterson's curse) were the first to emerge and respond to watering. Several exotic species not detected in the vegetation surveys were identified including the variegated thistle, *Silybum marianum* and the scarlet pimpernel, *Anagallis arvensis*. This experiment could indicate future weed problems under changed climatic conditions or disturbance regimes.

The native plant species are growing and flowering much more slowly than most of the exotic species and the correct identity of many will not be known for months. Cane wire grass (*Aristida ramosa*) and wallaby grass (*Austrodanthonia* sp.) are the two most common native grasses recorded so far, and it is promising to note that they were found at sites where only exotic species were recorded in the understorey vegetation. Other important native forbs such as Austral Sunray (*Triptilodiscus pygmaeus*) and Smooth Solenogyne (*Solenogyne dominii*) were also found in higher abundance in the seed bank than in the field. Native species that prefer moist conditions, including sedges (Cyperaceae family) and woodrushes (Juncaceae family), which had not been found in the field over the past three years were found to germinate under the moist glasshouse conditions.

Many non-vascular plants rarely seen in the field have been grown from the soil samples including a variety of hornworts, liverworts, mosses and lichens.

Removal of livestock grazing appears to have altered the seed bank, with both the composition and abundance of species differing between livestock grazed sites and ungrazed sites. So far the ungrazed sites have the greatest diversity and abundance, and sites managed as travelling stock routes the lowest diversity and abundance. The landscape location of the woodland also appears to have affected the seed bank, with a large difference detected between sites in a predominantly grazing landscape compared to those that were in the more intensive grazing and cropping landscape.

It is expected that this study will conclude early in 2009. The diversity and abundance of germinants so far suggests that the seed bank could play an important role in restoring the understory of woodland remnants. Just as past and current management practices impact the current standing vegetation, they also appear to impact the capacity of seed bank to germinate.

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The understory of this yellow box gum woodland near Young is now dominated by annual exotic grasses, but there are seeds of native grasses and forbs still present in the soil.

Managing coastal vegetation to reduce weed invasion

Tanya Mason and Kristine French, University of Wollongong

Coastal dune vegetation in eastern Australia has been extensively invaded and degraded by bitou bush (*Chrysanthemoides monilifera* ssp. *rotundata*).Public and private land managers and community groups have responded by actively controlling bitou bush infestations. However, as control is achieved at individual sites, better information is needed about how to effectively restore dune communities so they will strongly resist bitou bush reinvasion from soil-stored seed or dispersal from adjacent infestations.

Over the past 18 months glasshouse and outdoor experiments have been conducted to investigate how to improve the resilience of the plant community to bitou bush invasion. In glasshouse experiments, the performance of 18 native species, commonly found in dune communities of coastal New South Wales was investigated. These species represent three growth forms (grasses, herbs, shrubs) and were grown as seedlings in competition with bitou bush seedlings. The experiment was run for five months, and at its conclusion,it was found that all native species are poor competitors against bitou bush. In fact, bitou bush performance was much more dependent on the availability of water than affected by which native plant was growing alongside it. This research has highlighted that bitou bush is dominant at the seedling stage and land managers need to rigorously follow up control programs to minimise the number of bitou bush individuals competing at native regeneration sites.

In outdoor experiments, corrugated iron water tanks were converted into large-scale pots by filling them with dune soil and planting them with combinations of different growth forms, simulating communities with different functional diversities. For one subset of pots the planting of functional groups was staggered. This was used to simulate the different arrival orders that might naturally result in lags in dispersal or in restoration projects where species are planted at two different times. After allowing the native species to establish, the researchers introduced bitou bush seed and monitored how well bitou seedlings established in each of our constructed communities.

Dr Kristine French adding fertiliser to the Mesocosm experiment — winter 2007. Photo by E. Ens

Bitou Bush along fenceline in Puckeys Estate, Wollongong. Photo by K. French

Mesocosm experiment — spring 2008. Photo by Dr Tanya Mason

Grass monocultures grown with six grass species were more effective than other functional group combinations (shrub monocultures, herb and shrub polycultures and polycultures with variable arrival orders) in reducing bitou bush germination. The superior resilience of grass monocultures may be attributable to the low availability of bare ground in these pots, which may have inhibited bitou bush germination. While grass monocultures may be most resilient to bitou bush invasion in the short term, these communities do not maximise the biodiversity values of restored communities. It is therefore recommended that a suite of native rhizomatous grass species are included in restoration planting activities, and that other functional groups are also actively reintroduced to restoration sites to maintain species richness at restored sites.

Research such as this is important in understanding how indigenous species interact and how bitou bush changes biotic and abiotic resources in dune communities.

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Dr Tanya Mason in the glasshouse. Photo by Dr Kristine French

Fenceline contrast, showing that Serrated Tussock can be managed, Photo by Aaron Simmons

Serrated tussock control in native pastures

Aaron Simmons, Charles Sturt University

Serrated tussock is a perennial grass and a Weed of National Significance (WoNS). It is highly unpalatable to livestock and invades grasslands and pastures of the cooler areas of south-eastern Australia, including Tasmania. Serrated tussock control in arable areas that are suitable for improved pastures is well known and relatively simple, but control of serrated tussock in native pastures is a much more difficult proposition. Areas left to native pastures are often steep and/or inaccessible and are likely to have soils with poor fertility, attributes that make the sowing of pastures uneconomical and/or impractical.

The densities of serrated tussock infestations in native pastures are not uniform. A project funded through Land & Water Australia's Defeating the Weed Menace R&D program, and run by researchers from the EH Grahame Centre for Agricultural Innovation, Charles Sturt University, set out to investigate why some paddocks had little or no serrated tussock, yet an adjacent paddock under different management had a high density infestation.

Researchers visited twenty sites with each site consisting of paired paddocks under different management, with contrasting levels of serrated tussock. The manager of each paddock was interviewed about how the paddock had been managed in the past (e.g. disturbance, fertiliser history, stock type, stocking rate), and their level of knowledge on current serrated tussock best management practices and impediments to control. Pasture composition of the paddock was also determined, and soil samples were taken to determine the numbers of potential seedlings in the soil seedbank.

Key findings of the study were that disturbance (the removal of competitive species by overgrazing or broadacre herbicide applications) plays a key role in the establishment of serrated tussock. Using minimal disturbance control techniques, such as chipping and spot spraying, is essential to reduce the rate of re-invasion. Any seed in the seedbank provides the opportunity for invasion to occur. Constant and vigilant control that creates minimal disturbance, and therefore maintains competition, is essential to stop germinating seeds from becoming established plants.

There were no differences in the knowledge possessed by managers of contrasting paddocks. Farmers with high densities of serrated tussock reported a greater number of perceived impediments, but recognised that an absence of control will lead to an increase in density of an infestation. It is a popular belief that grazing a pasture with sheep leads to more serrated tussock than if it were grazed with cattle, but that belief was not supported by the findings of the project.

High density infestation of Serrated Tussock. Photo by Aaron Simmons

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The spread and detection of weeds on Australian farms

Professor Brian Sindel, University of New England

Despite the $4 billion annual cost of invasive weeds to the Australian economy through lost agricultural production and the devastating impact of weeds on natural ecosystems, no comprehensive studies have previously been undertaken to ascertain how weeds spread once present within Australia, or how farmers and weeds inspectors go about detecting new weeds.

Two recent University of New England research projects, led by Professor Brian Sindel of the School of Environmental and Rural Science and funded by Land & Water Australia's Defeating the Weed Menace program, sought to assess the relative risks of sources (sites) and pathways (means) of weed spread within Australia and to identify ways to:

- reduce these risks
- assess current weed surveillance levels and practices amongst landholders and weeds inspectors and
- identify ways to improve weed detection by these groups on-ground.

As Professor Sindel noted, "most recently naturalised species are still only locally distributed, and so it is critical to identify the primary pathways for the spread of these, as well as more widespread weeds, so as to be able to prevent movement to un-infested areas. If weeds do move to new areas then early detection is the first step in their control".

An evaluation of Australian and international literature identified twenty-four weed sources and seventeen weed pathways (both natural and a consequence of deliberate and accidental human activity) for weed spread (see table 1).

Concerned landholders and researchers inspect paddocks on the south coast of NSW where fireweed (Senecio madagascariensis) is spreading. Photo by Brian Sindel

After scoping the issues with focus groups, Professor Sindel and his colleagues then undertook three national surveys in late 2007 and early 2008 of over 100 weed professionals, 600 landholders, and nearly 150 weed inspectors, drawing on their knowledge about how weeds spread and their detection in the Australian context.

Weed sources

The survey of weeds professionals found that the most important of the weed sources identified in the review of literature include transport sites (roads, railways, water courses and airports), land in transition (degraded or abandoned land), pastures and rangelands, ornamental horticulture sales sites, and private gardens.

Weed spread pathways

Weeds professionals were also asked to evaluate each weed spread pathway with regard to:

- its capacity to transport propagules (seeds) and facilitate weed spread
- the effectiveness of current regulatory and management structures seeking to negate the pathway
- the expected importance of the pathway in the future.

Each pathway was found to have a relatively high overall capacity to facilitate weed spread. However, fodder trade, aquarium plant trade, agricultural produce, ornamental plant trade, water, and machinery and vehicles were considered particularly capable. Research sites, revegetation and forestry activities, and food plant trade were considered relatively less capable pathways.

According to farmers and weeds inspectors, weeds are most likely to spread onto farms via birds, wind, water, vehicles, machinery, livestock and fodder.

At least 50 per cent of weeds experts surveyed considered that the current regulatory and management arrangements are inadequate for each weed spread pathway. This was particularly apparent in relation to the plant trade pathways (ornamental, aquarium, medicinal and food plants), fodder trade, and revegetation and forestry.

A variety of management improvements were suggested, including targeted education and extension activities, improved weed risk assessment processes, further research into control measures, enforced control of specific weeds and pathways, and extra staff and resources.

Table 1: Weed spread pathways in Australia

- ***Deliberate Spread by Humans***
  - Ornamental plant trade
  - Mail order plant trade
  - Aquarium plant trade
  - Medicinal plant trade
  - Food plant trade
  - Fodder trade
  - Revegetation and forestry
- ***Accidental Spread by Humans***
  - Human apparel and equipment
  - Machinery and vehicles
  - Construction and landscaping materials
  - Agricultural produce
  - Research sites
  - Livestock movement
  - Waste disposal
- ***Natural Spread***
  - Birds
  - Other animals
  - Wind
  - Water

The future importance of weed spread pathways

Many experts indicated that 'natural' pathways of weed spread (water, wind, birds and other animals) are likely to remain as important in the future. Pathways involving human activity that appear likely to increase in importance include fodder trade, ornamental and aquarium plant trade, agricultural produce, and machinery and vehicles.

Management of weed spread in the context of gardening and landscaping, agricultural production, and natural resource management appears likely to become more crucial over time, due to:

- the increasing popularity of gardening
- landscape fragmentation and growth of peri-urban zones
- the declining number of herbicides available for use in waterways
- projected climatic variability, leading to a need for drought-tolerant food, fodder and ornamental plant species, and perhaps enhancing the capacity of natural pathways to carry viable seeds.

Weed detection

The surveys of farmers and weeds inspectors found that the great majority of farmers check for new weeds on their properties on a regular basis, often while undertaking other farm operations, and are hungry for information on weeds for which they should be particularly on the look out. Nearly two thirds of farmers said that they would look for new weeds whether or not they were declared under legislation, and that distribution information on weeds on private land should be made publicly available in order to help with better management planning.

According to survey respondents, the most likely places to find new weeds on farms were along water courses, traffic areas and boundaries with neighbours. The best time to look for new weeds varied with climate and type of farm operation, but related particularly to when weeds were actively growing and recognisable.

Professor Sindel concluded that, "farmers and weeds inspectors are highly committed to the detection, prevention and management of new weeds and should be encouraged in this role by government for the benefit of all Australian landscapes and communities".

Further information:

The final project report is available from LWA, and is also free to download from **lwa.gov.au/weeds**

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Birds, such as this King Parrot, are believed by farmers and weeds inspectors to be a major pathway for the spread of weeds such as this Cotoneaster. Photo by Brian Sindel

What do you get when you strap a rotor to a weed controller?

Associate Professor Salah Sukkarieh, Australian Centre for Field Robotics, The University of Sydney

In the 2007/08 Defeating the Weed Menace R&D program a novel approach to the detection and eradication of emerging aquatic weeds was presented. The Australian Centre for Field Robotics (ACFR) at the University of Sydney proposed the development of an autonomous weed controller: one that wouldn't tire, would travel large distances, and wouldn't mind traversing through difficult to access areas in the hope of detecting and eradicating nasty weeds — and so it was, the Weedinator was born.

The ACFR are world renowned for their exploitations in autonomous systems — basically robots that can do all the "dull, dirty and dangerous" tasks that are out there. The group has worked on novel systems, delivered a number of world firsts, and commercialised many of their products in the areas of logistics, mining, defence, agriculture and art.

The proposal put forward for the DWM program was to develop a prototype aerial robot that would house sensors and spray systems. The sensors would take imagery of the environment that the robot flew over, classify the imagery so as to detect where the weeds were (if any), and geo-reference the location of those weeds. The robot could then spray the weeds, or be tasked to go back to those weed locations and spray them.

The project was divided up into two key areas:

1. The development of the robotic platform
2. The development of novel algorithms for the detection of weeds.

The platform was a modified model helicopter. Using a helicopter meant full manoeuvrability could be attained, including hover, thus giving the ability to traverse large distances, move into tight situations, and hold position to take imagery or to spray. This involved development and tuning of flight control and navigation algorithms, as well the spray mechanisms. The final system could fly for approximately two hours and carry approximately 500ml of herbicide (although water was used in this project for demonstration).

The detection algorithms were based on novel machine learning techniques that are currently very popular in the scientific community. The basic principle is that instead of developing algorithms that specifically try to model what a weed is (this approach has always failed in the past), why not develop an algorithm that learns the model itself? Such approaches mimic the way the human brain learns. With such an algorithm you give it many images of the weed of interest, and many images that are not the weed of interest. You tell the algorithm which is what, and then leave it alone while it learns the key differences, focussing on qualities such as colour, shape and texture.

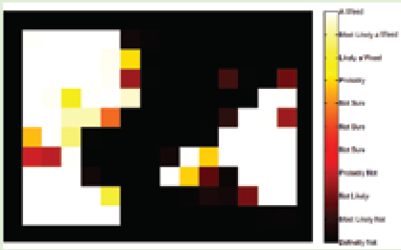
The algorithms proved to be very robust and accurate and were tested on Alligator weed and sprayed Salvinia.

Images show the original image, and beneath it the result from the classification algorithm, showing the likelihood of the element within the image being a weed.

1. A photo of the aerial robot. The aluminium casing at the front of the robot houses the computer processing and imaging sensors. The two boom arms and spray module deliver the spray (water in these tests) to the desired location. Photo by Muhammad Esa Attia

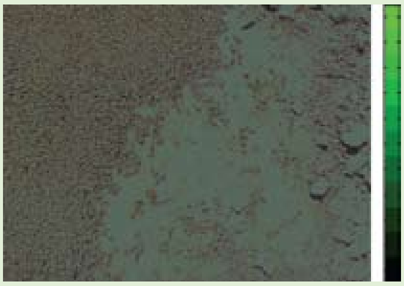
2a. A aerial image of Alligator weed and a tree trunk.

The robotic aerial vehicle over sprayed Salvinia. Photo courtesy of Muhammad Esa Attia

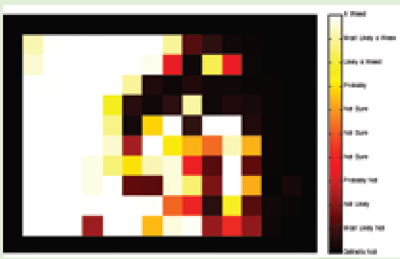


2b. Processing algorithms showing the results of the classification of the Alligator weed. The legend on the right indicates the probability of a detected weed.

Photo of the aerial robot in action, conducting aerial surveying and classification. Photo by Muhammad Esa Attia



2c. Aerial image of sprayed Salvinia.



2d. Image processing algorithms showing the results of the classification of the sprayed Salvinia image. The legend on the right indicating the probability of a detected weed.

The ACFR also worked in collaboration with a number of industry and government groups, including the NSW Department of Primary Industries, Sunwater and Farm and Dam Control. Within this collective setting they were able to gain a substantial understanding of the weed management operations, as well as define pathways for this technology to be incorporated into current weed management cycles.

The future looks very exciting for this little intelligent machine. The ACFR plans to continue on with the project with a specific focus on aquatic weeds, and to also broaden its capabilities into other ecology management arenas.

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Sources of further information:

Land & Water Australia, Defeating the Weed Menace R&D program **lwa.gov.au/weeds**

Australian Government weeds information site **weeds.gov.au**

Australian Weeds Research Centre **daff.gov.au/natural-resources/invasive/australian_weeds_research_centre**

Bureau of Rural Sciences Weeds Research **daff.gov.au/brs/land/weeds**

Weeds Australia National Portal **weeds.org.au**

CRC for Australian Weed Management **weedscrc.org.au**

National Land and Water Resources Audit **nlwra.gov.au/national-land-and-water-resources-audit/weeds**

Council of Australasian Weed Societies (state and territory societies can be accessed through this site) **caws.org.au**

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