NATIONAL WEEDS RESEARCH

A summary of research outcomes from the National Weeds and Productivity Research Program 2011-2012

LEADING THE SEARCH FOR WEED SOLUTIONS

OCTOBER 2012
RIRDC Publication No. 12/079
NATIONAL WEEDS RESEARCH

A summary of research outcomes from the National Weeds and Productivity Research Program 2011-2012

ISSN: 1440-6845
Publication No.: 12/079

The information contained in this publication is intended for general use to assist public knowledge and discussion and to help improve the development of sustainable regions. You must not rely on any information contained in this publication without taking specialist advice relevant to your particular circumstances.

While reasonable care has been taken in preparing this publication to ensure that information is true and correct, the Commonwealth of Australia gives no assurance as to the accuracy of any information in this publication.

The Commonwealth of Australia, the Rural Industries Research and Development Corporation (RIRDC), the authors or contributors expressly disclaim, to the maximum extent permitted by law, all responsibility and liability to any person, arising directly or indirectly from any act or omission, or for any consequences of any such act or omission, made in reliance on the contents of this publication, whether or not caused by any negligence on the part of the Commonwealth of Australia, RIRDC, the authors or contributors.

The Commonwealth of Australia does not necessarily endorse the views in this publication.

This publication is copyright. Apart from any use as permitted under the Copyright Act 1968, all other rights are reserved. However, wide dissemination is encouraged. Requests and inquiries concerning reproduction and rights should be addressed to the RIRDC Publications Manager on phone 02 6271 4165.

In submitting this report, the researchers have agreed to RIRDC publishing this material in its edited form.

RIRDC Contact Details
Rural Industries Research and Development Corporation
Level 2, 15 National Circuit
BARTON ACT 2600
PO Box 4776
KINGSTON ACT 2604
Phone: 02 6271 4100
Fax: 02 6271 4199
Email: rirdc@rirdc.gov.au
Web: http://www.rirdc.gov.au

Electronically published by RIRDC in October 2012
Print-on-demand by Union Offset Printing, Canberra
at www.rirdc.gov.au or phone 1300 634 313

COVER IMAGE: Mission grass Pennisetum polystachion
Foreword

Australia’s primary producers are some of the most innovative and productive in the world. Ongoing government and industry commitment to rural research, development and extension (RD&E) is helping keep our producers on the front foot. This is also the case when it comes to managing the impact of weeds on farm and forestry productivity.

I am pleased to introduce the Rural Industries Research and Development Corporation’s summary of research outcomes from the National Weeds and Productivity Research Program. The program focused on cross-sectoral research tackling the spread and impact of weeds across the country. We have invested in a range of projects to meet the government’s priorities of improving productivity and the environment.

The individual research projects have developed new information and approaches that aim to:

• reduce reliance on herbicides, energy and chemical inputs in agriculture;
• refine integrated weed management strategies to manage risks across diverse agricultural landscapes, globalised trade and a changing climate;
• identify motivators and barriers to the uptake of cost-effective weed management practices;
• improve our understanding of the economic, social and environmental impacts of invasive plants, and
• guide collaboration between researchers, land managers and regulatory agencies into the future.

In July 2012 I launched the Australian Government’s RD&E policy statement. This reiterated the government’s commitment to rural R&D and the Rural Research and Development Corporation (RDC) model. The government is building on its strong history of collaborating with our rural sector on research and development, contributing more than $700 million annually through RDC’s, Cooperative Research Centres, CSIRO and universities.

For its part, the results of the National Weeds and Productivity Research Program demonstrate the success and efficiency RDCs can achieve through well planned cross-sectoral research.

Our work to establish a national biosecurity research, development and extension framework continues. I look forward to continue working with you, to ensure that national weeds research outcomes are adopted and built on in the future.

Senator the Hon. Joe Ludwig
Minister for Agriculture, Fisheries and Forestry

Overview

The summary reports included in this publication have been placed in one of three groups so that their relevance can be more easily understood. The three groups are Agricultural, Environmental and Agricultural and Environmental. The keys that appear with each report are shown here.
Weeds are one of the major threats to Australia’s primary production and to the natural environment.

The scourge of weeds costs Australian agriculture more than $4 billion dollars each year, including control costs and lost production.

Comprehensive research, followed by action on the ground is required to prevent this cost from increasing. During 2011-12 the National Weeds and Productivity Research Program, managed by the Rural Industries R&D Corporation, invested up to $12.4 million in more than 50 research projects that will improve our knowledge and understanding of weeds.

The research carried out as part of the RIRDC Weeds Program was varied and comprehensive. A lot of the research will provide land managers with the knowledge and tools to control weeds and reduce their impact on agriculture and biodiversity.

This publication, which provides a summary of each of the research projects, represents the conclusion of the research phase, however the knowledge and information generated will be utilised for many years to come.

If some of this research hasn’t already resulted in practical on-the-ground outcomes or tools then it will undoubtedly act as a foundation for further research that will.

This publication also represents the conclusion of the National Weeds and Productivity Research Program and the funding that it provided. It is vitally important that a national and centrally-coordinated research effort into weeds does not cease.

Weeds research requires a long-term funding commitment to maintain momentum in addressing the on-going challenge of finding weeds solutions and to protect the knowledge and skills base of the weeds research community.

A nationally coordinated weeds research program is needed to provide an over-arching, cross-sectoral approach to weed research and management. It should also support an Australia-wide approach to weed spread prevention.

Similarly, a nationally endorsed surveillance strategy could support state-led approaches to early detection and weed spread prevention and could provide tools to help weed managers, including industry, reduce the impact of weeds.

The significance of the weeds problem was recognised in early 2012 by the addition of 12 new weeds of national significance (WONS). If nothing else, the addition of 12 new weeds to the WONS list indicates the weed problem in Australia is getting bigger, not smaller.

The strategies set out for dealing with these new WONS identify the need for further research to improve understanding and treatment options. Treatment of WONS requires a nationally coordinated approach, including on-going research to provide the knowledge and understanding of these weeds, and to provide land managers with the tools to control them and minimise their impact on agriculture and biodiversity.

This publication is a summary of the comprehensive and important research that has been carried out as part of the National Weeds and Productivity Research Program. It leaves us better informed and greatly more knowledgeable than we were before the research began. This has been important research, and research that needs to be built upon for us to successfully fight the challenges that weeds bring.

Hon. John Kerin AM
Chairman
RIRDC Weeds Advisory Committee
## Contents

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Who’s involved with weeds? A social network analysis of community networks involved in weed management</td>
<td>6</td>
</tr>
<tr>
<td>Climate change impacts on agricultural weeds in WA (Phase II)</td>
<td>8</td>
</tr>
<tr>
<td>Harvest weed seed control workshops and evaluation of the Harrington Seed Destructor (HSD)</td>
<td>10</td>
</tr>
<tr>
<td>Golden dodder – developing novel detection methods using DNA assays and aerial imagery</td>
<td>12</td>
</tr>
<tr>
<td>Sustainability of wheat-selective pre-emergent herbicides in a changing climate</td>
<td>14</td>
</tr>
<tr>
<td>Innovations in institutions to improve weed funding, strategy and outcomes: research agenda</td>
<td>16</td>
</tr>
<tr>
<td>Minor use of chemicals</td>
<td>18</td>
</tr>
<tr>
<td>Risk assessment and management of paraquat resistance in the pasture seed industry</td>
<td>20</td>
</tr>
<tr>
<td>Tackling Australia’s weed seed liability with the Seed Persistence Tool Kit</td>
<td>22</td>
</tr>
<tr>
<td>Collation of information on weeds into the National Plant Health Status Report</td>
<td>24</td>
</tr>
<tr>
<td>Weed management under dry seeding and permanent residue farming practices</td>
<td>26</td>
</tr>
<tr>
<td>Paterson’s curse as a model to measure impact of climate change on biocontrol for weeds</td>
<td>28</td>
</tr>
<tr>
<td>Future proofing the National Post Border Weed Risk Management Protocol</td>
<td>30</td>
</tr>
<tr>
<td>Suppressive plants as part of an integrated management program for parthenium weed</td>
<td>32</td>
</tr>
<tr>
<td>Diagnostic tools for rapid detection of non-target-site metabolism-based herbicide resistance</td>
<td>34</td>
</tr>
<tr>
<td>Tools for adoption of optimal weed management strategies in cropping systems</td>
<td>36</td>
</tr>
<tr>
<td>Integrated weed management in vegetable crops: Gap analysis and RD&amp;E plan</td>
<td>38</td>
</tr>
<tr>
<td>Weed control in aerobic rice to increase water use efficiency</td>
<td>40</td>
</tr>
<tr>
<td>Alternative approaches to chemical weed control measures in new industries</td>
<td>42</td>
</tr>
<tr>
<td>Targeted control of seed production in the weed wild radish</td>
<td>44</td>
</tr>
<tr>
<td>Containment of invasive plants: a basis for decision making and best practice</td>
<td>46</td>
</tr>
<tr>
<td>Weed management on Indigenous lands: Indigenous values, perceptions and capacity</td>
<td>48</td>
</tr>
<tr>
<td>The use of weed sensors for variable rate herbicide application: Wimmera</td>
<td>50</td>
</tr>
<tr>
<td>Managing weeds on native title lands</td>
<td>52</td>
</tr>
<tr>
<td>Invasion and impact of high biomass grasses in Queensland</td>
<td>54</td>
</tr>
<tr>
<td>Desert Uplands: control of Parthenium and Mother-of-Millions</td>
<td>56</td>
</tr>
<tr>
<td>Precision sensing technology for infield identification of summer weeds</td>
<td>58</td>
</tr>
<tr>
<td>Systematic review of Australian weed-related social surveys</td>
<td>60</td>
</tr>
<tr>
<td>Just how bad are coastal weeds: assessing the geo-eco-psycho-socio-economic impacts</td>
<td>62</td>
</tr>
<tr>
<td>Biological control of sea spurge phase 1</td>
<td>64</td>
</tr>
<tr>
<td>Cabomba ecology and dispersal in Australia</td>
<td>66</td>
</tr>
<tr>
<td>Biological control of crotton weed on Lord Howe Island</td>
<td>68</td>
</tr>
<tr>
<td>Genetic, reproductive and demographic facilitation of Sagittaria invasion</td>
<td>70</td>
</tr>
<tr>
<td>Expanding the aquatic herbicide list: a proactive approach</td>
<td>72</td>
</tr>
<tr>
<td>Biological control &amp; ecology of alligator weed</td>
<td>74</td>
</tr>
<tr>
<td>Manipulating weed successions when restoring native vegetation communities</td>
<td>76</td>
</tr>
<tr>
<td>How do decisions by stakeholders affect weed distribution at a landscape scale</td>
<td>78</td>
</tr>
<tr>
<td>Biological control of Hudson pear in Australia</td>
<td>80</td>
</tr>
<tr>
<td>Climate change and the risk of weed invasions in the Murray Darling Basin</td>
<td>82</td>
</tr>
<tr>
<td>A microwave system to kill weed seedlings without herbicide</td>
<td>84</td>
</tr>
<tr>
<td>Biocontrol of prickly acacia: host specificity testing of new agents from India</td>
<td>86</td>
</tr>
<tr>
<td>The weight of the vine: Impacts of vine infestations on plant health</td>
<td>88</td>
</tr>
<tr>
<td>Weed risk assessment for Australian nursery &amp; garden industries</td>
<td>90</td>
</tr>
<tr>
<td>Biological control of weeds in south eastern Australia</td>
<td>92</td>
</tr>
<tr>
<td>Management of glyphosate resistant weeds in non-agricultural areas</td>
<td>94</td>
</tr>
<tr>
<td>Reducing the impact of tropical grassy weeds through effective risk management</td>
<td>96</td>
</tr>
<tr>
<td>Biological control of Weedy Sporobolus Grasses (WSGs) by the fungus Nigrospora oryzae</td>
<td>98</td>
</tr>
<tr>
<td>Use of hyperspectral remote sensing for enhanced detection of weeds</td>
<td>100</td>
</tr>
<tr>
<td>A unified approach to evaluate fitness costs in herbicide resistant Lolium rigidum</td>
<td>102</td>
</tr>
<tr>
<td>Improving prevention and containment of serrated tussock in SW Victoria</td>
<td>104</td>
</tr>
<tr>
<td>Does the tolerance of weeds to herbicide change with elevated CO2?</td>
<td>106</td>
</tr>
<tr>
<td>Improving regional adoption of weed control</td>
<td>108</td>
</tr>
<tr>
<td>Weed management using fibres from agricultural wastes</td>
<td>110</td>
</tr>
<tr>
<td>The Development of a National Weeds Resource Information Portal</td>
<td>112</td>
</tr>
<tr>
<td>Dieback of Weeds of National Significance (WoNS): their cause and prospects for biocontrol</td>
<td>116</td>
</tr>
<tr>
<td>National Weeds Spread Prevention Initiative</td>
<td>118</td>
</tr>
<tr>
<td>National Weeds and Productivity Research Program Advisory Committee</td>
<td>122</td>
</tr>
</tbody>
</table>
Who’s involved with weeds? A social network analysis of community networks involved in weed management

Researcher/contact
Dr Lyndal-Joy Thompson
ABARES

What the report is about
This report examines the current networks in place for managing weeds in Australia, in particular the provision of funding and information through the weed governance system. This research employed a social network analysis approach to investigate where community groups and institutions (such as local and state government agencies) obtain weed related information and funding.

Who is the report targeted at?
The report is targeted at policy makers and people who design communications or programs for weed management in Australia.

Where are the relevant industries located in Australia?
Participants in the research were located across Australia, although survey responses were dominated by people in New South Wales, Victoria and Western Australia. Information was sought from community groups involved in weed management, industry, academics, regional NRM bodies and all levels of government. Landcare groups and local governments represented the largest number of survey respondents.

Background
The Caring for Our Country program (CiOC) administered by the Department of Agriculture, Fisheries and Forestry (DAFF) has an established network for distributing funds for weed management related activities. This network includes funds provided through Regional Landcare Facilitators and Landcare Groups, community grant competitive funding rounds and funding available through research and development corporations. In 2009-10 the Rural Industries Research and Development Corporation (RIRDC) was tasked with developing a five year strategic plan for weed research and managing the second stage of the National Weeds and Productivity Research Program. In 2011 RIRDC and CiOC commissioned the Social Sciences Section of ABARES to undertake a social network analysis of resource and information flows related to weed management. The report produced and published by RIRDC contains a description and the results of this research.
Aims/objectives

The aim of this project is to understand who is involved in engaging communities in weed management issues and how information and resources flow through community engagement networks focussed on weed management. Key questions addressed by this research include:

- Who (people, groups and organisations) are part of the formal and informal networks providing resources (financial and other) for weed management through community engagement?
- What are the pathways that information and resources take within the networks identified; can we identify brokers, gaps and barriers to the flows?

Methods used

A social network analysis approach was adopted for this research. This involved undertaking two surveys using the SurveyMonkey online survey system. One survey was directed towards community groups and another at institutions involved in some aspect of weed management, including on-ground works, program or policy design, funding, etc. Respondents were selected through online presence indicating involvement in weeds, databases and snowball sampling.

Results/key findings

The research indicates that involvement and interest in managing weeds is extensive and complex. There is a large public interest in weed management and sources of information and funding are found from multiple sources, though dominated by local and state government departments and regional NRM bodies. The program of funding directed through CfOC is primarily targeted at administration through regional NRM bodies; however a large amount of information and funding is delivered through local and state governments. Survey responses indicate a desire for better coordination of information and funding efforts between levels of government, and in particular the involvement more directly of local government. This coordination is complicated by the role of the Commonwealth and State governments under the Constitution and the impact of historical and current weed management legislation and funding arrangements.

Implications for relevant stakeholders

Improving the effectiveness of weed management governance in Australia will depend in the future of improved coordination of funding and information between various stakeholders, but in particular between levels of government (including regional NRM groups). Stakeholders should be aware of the implications of the different areas of responsibility for weed governance and in particular community groups could be better informed about roles and responsibilities of the different levels of government. State and local government, in particular, could benefit from greater inclusion in Australian Government driven policies programs.

Communications

Communication of this report was made through two national surveys. A report will be made publicly available through RIRDC.


(PRJ-007483)
Climate change impacts on agricultural weeds in WA (Phase II)

Researcher/contact
Dr Pippa Michael
Curtin University

What the report is about
This report explores the impact of climate change on priority agricultural weeds within Western Australia.

Who is the report targeted at?
Information from this report will be valuable to growers within the south-west WA agricultural region.

Where are the relevant industries located in Australia?
The output of this research will be of interest to stakeholders involved in management of agricultural weeds within the agricultural region of WA.

Background
The WA wheatbelt is an important agricultural region covering an area of approximately 14 million hectares that underpins Australia’s grain production. Over 95% of the grain harvested in this area is exported overseas. With the south-west of WA forecast to experience the greatest environmental impact of climate change, the development of predictive models to determine future weed threats to the agricultural industry is essential for early intervention and to enable adaptation measures to be put in place.

Aims/objectives
This project aimed to assess the current and future impact of high risk agricultural weed species within the WA wheatbelt, and to develop preventative management strategies in order to reduce this impact. Specifically, our objectives were to:

- Identify 10 high priority weed species within the WA wheatbelt and apply a weed risk assessment (WRA) model on each to determine relative weed threats,
- Develop CLIMEX models for the distribution of four priority species,
- Project the distribution in 2070 for each weed species under an IPCC4 climate change scenario, and
- Develop management strategies for adaptation responses to manage the changed weed threat.

Methods used
A list of 10 priority high risk agricultural weed species (Table 1) were determined under a climate change scenario from the WA wheatbelt during a workshop with weed experts using information sourced from field surveys and databases. Detailed weed risk assessments were produced for each of the 10 species using the 2008 South Australian Weed Risk Management Guide developed by the Department of Water Land & Biodiversity Conservation. CLIMEX models were then created for five of these species using information obtained from our growth chamber experiments, current distribution and known phenology. See Michael et al (2012ab) for detailed methodology on the modelling process and growth experiments.

“When projected to 2070 under a CSIRO Mk3 climate change scenario, the wheatbelt region continued to remain highly suitable for the growth of Chondrilla juncea, Conyza bonariensis and Rapistrum rugosum.”
Results/key findings

Table 1. Weed risk assessments of the top 10 priority weed species of the WA wheatbelt.

<table>
<thead>
<tr>
<th>Species</th>
<th>Common name</th>
<th>Comparative Weed Risk</th>
<th>Feasibility of Containment</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argemone ochroleuca</td>
<td>Mexican poppy</td>
<td>Negligible</td>
<td>Very high</td>
<td>Monitor</td>
</tr>
<tr>
<td>Boerhavia schomburgiana</td>
<td>tarvine</td>
<td>Negligible</td>
<td>High</td>
<td>Limited action</td>
</tr>
<tr>
<td>Carrichtera annua</td>
<td>Ward’s weed</td>
<td>Medium</td>
<td>Very high</td>
<td>Contain spread</td>
</tr>
<tr>
<td>Chondrilla juncea</td>
<td>skeleton weed</td>
<td>High</td>
<td>Medium</td>
<td>Protect sites</td>
</tr>
<tr>
<td>Conyza bonariensis</td>
<td>fleabane</td>
<td>Very high</td>
<td>Medium</td>
<td>Contain spread</td>
</tr>
<tr>
<td>Mesembryanthemum crystallinum</td>
<td>slender iceplant</td>
<td>Medium</td>
<td>High</td>
<td>Protect sites</td>
</tr>
<tr>
<td>Oncosiphon piluferum</td>
<td>globe chamomile</td>
<td>Medium</td>
<td>Very high</td>
<td>Contain spread</td>
</tr>
<tr>
<td>Rapistrum rugosum</td>
<td>wild turnip</td>
<td>Very high</td>
<td>High</td>
<td>Destroy infestations</td>
</tr>
<tr>
<td>Solanum elaeagnifolium</td>
<td>white horse nettle</td>
<td>Very high</td>
<td>Medium</td>
<td>Contain spread</td>
</tr>
<tr>
<td>Verbesina enceloides</td>
<td>crown beard</td>
<td>Negligible</td>
<td>High</td>
<td>Limited action</td>
</tr>
</tbody>
</table>

The five species chosen for CLIMEX modelling were Chondrilla juncea, Conyza bonariensis, Oncosiphon piluferum, Rapistrum rugosum and Verbesina enceloides. When projected to 2070 under a CSIRO Mk3 climate change scenario, the wheatbelt region continued to remain highly suitable for the growth of Chondrilla juncea, Conyza bonariensis and Rapistrum rugosum. For Verbesina enceloides, overall suitability increased under a climate change scenario whilst for Oncosiphon piluferum suitability decreased slightly.

Implications for relevant stakeholders

A list of priority agricultural weed species and predictive distribution models under a climate change scenario will enable growers to prevent future weed problems by putting in place pre-emptive management strategies.

Communications

PRESENTATIONS


Michael, P. J., Yeoh, P. B. and Scott, J. K. (2nd May 2012). Potential distribution of the Australian native Chloris truncata (windmill grass) based on modelling both the successful and failed global introductions. Department of Environment and Agriculture seminar series, Curtin University, Bentley campus, WA.

Michael, P. J., Yeoh, P. B. and Scott, J. K. (seminar to be given on 11th October 2012). Potential distribution of the Australian native Chloris truncata (windmill grass) based on modelling both the successful and failed global introductions. 18th Australasian Weeds Conference, Melbourne, Victoria.


PUBLICATIONS


(PRJ-006828)
Harvest weed seed control workshops and evaluation of the Harrington Seed Destructor (HSD)

Where are the relevant industries located in Australia?
The focus of this research was the development and promotion of harvest weed seed control systems for crop producers in southern and northern Australian cropping regions. Within this was the field evaluation of the HSD and other harvest weed seed control systems as well as the identification of the potential to target weeds during summer and winter crop harvest in the northern cropping region.

Background
Harrington Seed Destruction development.
The Harrington Seed Destructor has been developed in Western Australia with GRDC funding assistance to process chaff sufficiently to destroy weed seeds during the harvest operation. This system has proved effective in destroying the seed of several weed species that enter the harvester under commercial harvest operation. During the 2011 harvest, this system was compared with the other harvest weed seed control systems, narrow windrow burning and chaff carts under commercial harvest conditions across the southern Australian region in a range of crop production environments.

Harvest weed seed control in south-eastern and northern Australian cropping regions.
In order to combat herbicide resistant weed populations, harvest weed seed control systems have been widely adopted across the WA wheat belt to allow the continuation of intensive crop production systems. Across the southern Australian cropping region there has not been a similar focus on harvest weed seed control despite the occurrence of similarly escalating levels of herbicide resistance in the same weed species that plague WA producers. In northern Australian crop production regions the potential for targeting weed seeds during harvest has not been considered. The potential impact for harvest management of problem weed species needs to be assessed before the use of these technologies can be considered.

Aims/objectives
• Determine the effectiveness of harvest weed seed control systems in controlling annual ryegrass during commercial harvest in southern Australian wheat production systems.
• Promote the value of harvest weed seed control in southern Australian cropping systems
• Determination of weed seed management potential for northern crop production systems

Large scale replicated trial sites comparing commercial scale harvest weed seed control systems at 14 locations across south-eastern Australia during the 2011 harvest period confirmed the efficacy of the HSD in controlling annual ryegrass.
Methods used
Evaluation of the HSD and harvest weed seed management systems across southern Australian cropping region
The HSD system was definitively evaluated during the 2011 wheat harvest in commercial scale replicated trials at 14 sites across southern Australian cropping region. The harvest weed seed control systems of narrow windrow burning, chaff carts and HSD were compared with conventional harvest for annual ryegrass control in wheat crops. The effects of these treatments were assessed by monitoring subsequent annual ryegrass seedling emergence at the start of the 2012 growing season.

Harvest weed seed control seminars
Australian Herbicide Resistance Initiative (AHRI) has developed a half day farmer seminar on harvest weed seed control systems covering research and practical issues relevant for the successful implementation of these systems. Six seminars were delivered to farmers and advisors across the southern Australian cropping production region in September 2011.

Determining weed seed control potential for northern crop production systems
Weed seed retention surveys of summer and winter grown crops were conducted across the northern crop production region to identify the potential for harvest weed seed control systems. The focus of these surveys was to identify weed species with erect seed bearing plant parts allowing the collection of significant proportions of weed seed during crop harvest. Paddocks were surveyed just prior to crop harvest with data on weed species, presence, density and seed production collected.

Results/key findings
Evaluation of harvest weed seed control systems
Large scale replicated trial sites comparing commercial scale harvest weed seed control systems at 14 locations across south-eastern Australia during the 2011 harvest period confirmed the efficacy of the HSD in controlling annual ryegrass. All three harvest weed seed control systems, chaff cart, narrow windrow burning and HSD similarly reduced the subsequent emergence of annual ryegrass. At each site producers and agri-industry professionals were invited to observe the use of harvest weed seed control systems during harvest. Despite busy harvest schedules about 400 people took the opportunity to observe the use of these systems.

Harvest weed seed control workshops
Across seven locations over 200 growers and agronomists received the latest research information on the efficacy of the three harvest weed seed control systems, chaff carts, windrow burning and HSD and how these can practically be implemented in their local farming systems.

Determination of weed seed control potential for northern crop production region
A survey of winter grown wheat and chickpea crops in the northern cropping region identified the potential to collect and remove seed of several weed species during the harvest. Turnip weed and wild oat were identified as having very high proportions (>90%) of total seed production retained above harvest cutting height at wheat and chickpea crop maturity. Thus there is potential for harvest weed control systems to dramatically impact on the seed return of these species to the soil seed bank. Fleabane and sowthistle also had very high levels of seed retention above harvest cutting height at crop maturity. However, both species have a prolonged reproductive period and produce small seed with a pappus that facilitates wind dispersal. Just how much of this seed would be captured and destroyed is currently unknown.

Implications for relevant stakeholders
The results from these applied studies are of direct relevance to the Australian crop production industry. A key finding was the establishment of the efficacy of the newly developed HSD as being equivalently effective to existing harvest weed seed control systems. Thus a new weed control system is now being introduced to the industry. Equally significant were the results from the northern cropping region survey confirming the potential for harvest weed seed control systems to be used across all Australian crop production regions.

Recommendations
Further promotion of the results derived from this research will significantly value-add to this project. This study has clearly defined the potential for harvest weed seed control systems for the Australian crop production industry. Information produced as part of this project provides evidence for growers as well as agri-industry professionals on the use of these systems to effectively target weed seed production during crop harvest. Surveys of northern region crops established the potential for these systems in targeting problematic weeds within winter and summer crops. The field comparison of currently available systems across the southern Australian cropping region showed equivalent efficacy of the different harvest weed seed control systems in targeting annual ryegrass.

Communications
PRESENTATIONS
The weed seed control survey of winter crops results have been presented at the Goondiwindi updates. Results from this project will be presented at the “Global Herbicide Resistance Challenge”, an international Conference to be held in Perth, on February 18-22, 2013.

PUBLICATIONS
Walsh, M.J. Aves, C. and Powles, S.B. Impact of harvest weed seed control systems on Lolium populations in southern Australian wheat production systems (for submission to Weed Technology Journal)
Widdicker et al. What percent of northern weed seed might it be possible to capture and remove at harvest time? A scoping study (GRDC Goondiwindi Crop updates 2012)
Walsh, M.J. (2013) Herbicide resistance management in Australian wheat production systems. (Book chapter from Global herbicide resistance conference proceedings)
A manuscript is in preparation on the results generated from the large scale southern region trials focussing on harvest weed seed control system.

(PRJ-006834)
Golden dodder – developing novel detection methods using DNA assays and aerial imagery.

Researcher/contact
Dr John Heap
SARDI

What the report is about
This report summarises research aimed at developing better detection methods for golden dodder (Cuscuta campestris) to reduce its spread. Golden dodder threatens many agricultural industries, including Australia’s valuable lucerne seed and white clover seed export industries.

Who is the report targeted at?
This report is targeted at agricultural producers (including Lucerne Australia), government agencies, and research scientists.

Where are the relevant industries located in Australia?
In the short-term, golden dodder most seriously threatens the $28 million per year lucerne and white clover seed industries in the Upper South East of South Australia and Western Victoria. In the medium term, many summer-grown irrigated vegetable crops are at risk in all areas of Australia. The immediate beneficiaries of this research will be the lucerne seed and white clover seed growers.

Background
Golden dodder continues to spread and it is difficult to detect new infestations. Once seed has entered the soil seed bank, the site must be treated and monitored for decades because seed life is very long. New infestations are most often discovered by seed cleaners during routine manual visual inspection of harvested lucerne and white clover seed.

Development of DNA tests and remote-sensing techniques has the potential to improve dodder detection. DNA tests were also evaluated for two other weeds of significance for the small seeds industries: branched broomrape (Orobanche ramosa; existing test) and perennial thistle (Cirsium arvense; new test developed).

Aims/objectives
The project aims to benefit small seed growers by protecting the industry from new golden dodder incursions. The research has two objectives:

Objective 1: Develop a DNA assay to improve detection of dodder seed in commercial seed;

Objective 2: Develop remote sensing image analysis techniques to identify golden dodder infestations in lucerne crops and riverine natural vegetation area.
Methods used
DNA sequences for golden dodder and perennial thistle were used to design primers and probes for the DNA assays. Dodder and perennial thistle leaf samples and seeds were used to confirm specificity, sensitivity, and usefulness against target weeds. Four band (red, green, blue, infra-red) multi-spectral remotely-sensed imagery was collected over golden dodder patches using a remotely-controlled camera plane (UAV), piloted aircraft, and satellites. Multi-spectral and hyper-spectral reflectance (spectral fingerprint) data was extracted from golden dodder, green plants, soil, and red gums for comparative analysis.

Results/key findings
DNA tests: DNA tests for golden dodder and perennial thistle were successfully designed and tested. The golden dodder test was specific to a group of species in Cuscuta, and consistently detected golden dodder in length separator offal, gravity table offal, and lucerne seed with a sensitivity threshold of 2 to 3 seeds per 250g samples. The perennial thistle test was specific to Cirsium arvense, and reliably detected single seeds of the thistle in 250g samples. The branch broomrape test detected branched broomrape seeds in lucerne seed with a sensitivity threshold below 10 seeds per 100g.

Remote-sensing: An array of algorithms, using four-band reflectance values, was investigated to discern golden dodder patches. Results were generally disappointing, however the “Red Blue Green Red (RBGR) index” = (R-B)/(G/R) discriminated golden dodder at several sites, but not others. Airborne and satellite imagery had lower spatial resolution than UAV imagery and was no better than UAV imagery. The small size (0.5 to 2m diameter) and thin stems of golden dodder patches in lucerne produced reflectance that was highly mixed and dominated by green host signal. Analyses of hyper-spectral data suggested that sensing in custom wavebands may have potential. Preliminary experiments were conducted sensing 610 and 800 nm wavebands.

Additional findings: Additional research showed that the golden dodder test was surprisingly sensitive when applied to dust samples. The test can detect less than 0.1mg dodder dust in 250g offal samples. Real dust from a commercial header exposed to golden dodder infestations tested positive from sweepings inside and outside of the machine. The golden dodder test also provided molecular evidence that two Cuscuta spp. populations in SA were different, and aligned most closely to published sequences of Cuscuta tasmanica.

Implications for relevant stakeholders
Industry and policy makers: Potential access to three DNA tests to improve detection of weed seeds, and potential for use of golden dodder dust detection to monitor headers and cleaning sheds.

Communities: More resilient seeds industry with reduced risk, to underpin local economies.

Taxonomists: Molecular information about putative C. suaveolens and C tasmanica populations.

Recommendations
Investigate the potential for commercial provision of the three DNA tests to industry.

Consider the potential use of golden dodder dust detection for surveillance and monitoring.

Communications
Dr Heap gave a keynote address to the Weed Management Society of SA conference on May 8th 2012, and gave the Lucerne Australia executive a detailed briefing on May 10th 2012. He also gave a presentation to the Lucerne Seed Industry Conference on Sept 19th 2011, and has met with seed industry personnel, inspected seed cleaning plants, and spoken about the project at a seed industry field day. Two rural newspaper articles were also been published.

(P RJ-006872)

“Potentially stakeholders will have access to three DNA tests to improve detection of weed seeds, and potential for use of golden dodder dust detection to monitor headers and cleaning sheds.”
Sustainability of wheat-selective pre-emergent herbicides in a changing climate

Researcher/contact
Dr Roberto Busi
University of Western Australia

What the report is about
Herbicides remain the pivotal strategy to remove weeds, one of the greatest factors in crop losses, and the evolution of herbicide resistance in weeds and climate change are probably the two greatest challenges to global food production. Sustainable use of herbicides is essential to ensure a viable and productive future for grain production worldwide in order to continue to feed our growing population. This study was focused on the risk of herbicide resistance evolution to two important herbicide options for ryegrass (Lolium rigidum) control in wheat. Wheat is the most important crop in Australia and ryegrass the most damaging weed.

Where are the relevant industries located in Australia?
Grains industry located mainly in the Southern and Western regions of Australia.

Background
The evolution of herbicide resistance in weeds and climate change are probably the two greatest challenges to global food production. Research studies demonstrate that repeated selection can shift ryegrass populations towards herbicide resistance especially if reduced (below-label) herbicide rates are used. Because of climate change, a different rain pattern has been observed in several areas of the Australian wheatbelt, showing a delay in substantial rains to allow a normal break of the season. This has led to increased weed pressure and reliance on pre-emergence herbicide treatments incorporated at sowing, because often seeding is delayed without using pre-seeding burn-down herbicide treatments. The study focused on assessment of the risk for herbicide resistance to new wheat-selective pre-emergence herbicides.

Aims/objectives
• Assess the response of the progeny and the parental populations after two generations of herbicide selection at the label rate.
• Analyse data from selection experiments and previously completed work to assess the risk of herbicide resistance evolution.
• Conduct modelling simulations were conducted to represent the effects of climatic factors and assess how these might influence predictions and recommendations regarding resistance evolution.
• Disseminate results to growers, consultants and scientists.

“Modelling simulations suggest rotation of trifluralin, Sakura® and Boxer Gold® is likely the most effective measure to delay the evolution of resistance to these herbicides.”
Methods used
Recurrent selection with the two herbicides Boxer Gold® and Sakura® was conducted on diverse ryegrass populations and the response of the progeny was assessed and compared to the parental populations. A large number of populations were screened and selection occurred for two generations. The dynamics of resistance evolution to two new herbicides for ryegrass control Boxer Gold® and Sakura® was evaluated in a final study in 2012. Data from this and previous studies were used to assess the risk of herbicide resistance evolution. The Polygenic Evolution of Resistance To Herbicides (PERTH) model was extended to incorporate climatic variability and climatic change and simulate the way that climate interacts with genetics, management, weed biology and herbicide efficacy to affect herbicide resistance evolution rates. It was also adapted to enable it to represent the evolution of resistance to two or more herbicides simultaneously. The model was then parameterised based on the empirical results showing levels of cross resistance between the herbicides. These extensions enabled the model to be used to investigate strategies for rotating the new pre-emergent herbicides with the ones currently used in current and projected climates.

Results/key findings
At present, herbicide treatments remain pivotal in any short term strategy to maximize crop yields and a more comprehensive understanding of herbicide resistance evolutionary dynamics is an important factor to help design pre-emptive strategies to delay, minimize and manage weed resistance, especially for new herbicides. In this study a limited number of ryegrass populations exhibited the potential to evolve resistance to either pre-emergence herbicides Boxer Gold® and Sakura® following repeated use of the recommended full label rate. Cross-resistance to Boxer Gold® and Sakura® following herbicide selection, is possible in ryegrass in particular populations displaying broad-spectrum resistance to multiple different herbicide modes of action. No correlation was evident between geographic distribution and risk of resistance evolution to Boxer Gold® and Sakura®. Modelling indicated that projected climate changes were unlikely to significantly change rates of evolution of herbicide resistance in themselves, although it may cause an overall reduction in weed populations due to increased drought stress. However, delayed ‘breaks to season’ reduce opportunities for pre-sowing burn-down herbicide applications and thus increase reliance on pre-emergent herbicides. This increased selection pressure will increase the rates of evolution of herbicide resistance. Drought stress may also reduce the efficacy of herbicides, leading to reduced kill rates, higher weed numbers, and possibly increased rates of evolution of herbicide resistance for certain situations where resistance is conferred by the combined effect of multiple genes (polygenic resistance).

Implications for relevant stakeholders
The potential for resistance evolution to Sakura® and Boxer Gold® has been examined in populations of annual ryegrass. Results were presented nationally and are immediately available so that there will be benefits associated to this information during the current 2012 growing season. Understanding the dynamics of resistance evolution associated with herbicide use reinforces the need of a better evolutionary informed weed management system. Sustainable use of herbicides is essential to ensure a viable and productive future for grain production in Australian and worldwide in order to continue to feed our growing population.

Recommendations
There is risk of resistance evolution by using below-label rates in cross-pollinated annual ryegrass as demonstrated by previous studies in ryegrass.

In this study a limited number of ryegrass populations exhibited the potential to evolve resistance to either the pre-emergence herbicide Boxer Gold® or Sakura® following repeated use of the recommended full label rate for two generations.

Modelling simulations suggest rotation of trifluralin, Sakura® and Boxer Gold® is likely the most effective measure to delay the evolution of resistance to these herbicides.

Weed population dynamics models should be used to estimate the risk associated with herbicide use and design integrated management strategies.

Communications
Results have been largely disseminated to growers, consultants and scientists website, newsletter, workshops, conferences and scientific journals. A number of papers are under review or in preparation to be submitted to relevant scientific journals and conferences for studies conducted under partial or full funding from RIRDC:

Busi R and Powles SB. Understanding resistance evolution to Sakura and Boxer Gold® in ryegrass populations. Perth Crop Updates, 28-29th February

Busi R, Gannes T, M Walsh and Powles SB. Understanding the potential for resistance evolution to the new herbicide pyroxsulfone: field screening at high versus recurrent selection at low doses. Weed Research, under review (IF = 1.622).


Renton M, Busi R and Powles SB. What is the best strategy for using new pre-emergent herbicides to avoid herbicide resistance? In preparation for Agricultural Systems.


(PRJ-006896)
Innovations in institutions to improve weed funding, strategy and outcomes: research agenda

Researcher/contact
Prof Paul Martin
University of New England

What the report is about
This report proposes a research agenda to support the development of a more effective institutional system in Australia for the management of weeds. By “institutions” we refer to the network of rules and the organisations that create or apply them. Institutions are responsible for key aspects of weed management including the creation and coordination of programmes, funding, and the development and application of knowledge. “Weeds governance” in this setting refers to the myriad of mechanisms used in order to alter the ways in which individuals and organisations operate in relation to the introduction or control of current or potential weeds.

The report addresses improved coordination and resourcing of ‘front line’ action, arrangements to improve knowledge about the human aspects of weed management, reduction of complexity and streamlining of institutional arrangements, and benchmarking of institutional arrangements.

Who is the report targeted at?
The primary target audience is policy makers, those who seek to influence invasive species policy, and providers of relevant research to policy makers. It is also anticipated that the results of this research will be relevant to broader ‘non-weed’ natural resource management.

Where are the relevant industries located in Australia?
Weeds occur in all areas of Australia, on land and in marine environments. They affect farming and other primary industries, marine industries, and are relevant in urban settings. All levels of government are also impacted.

Background
Professionals in weed management often express their frustration with the lack of private incentives for weed control, the insufficiency of government resources, the limitations of the legislation under which they work, and the difficulties of coordination across three levels of government within a federated system where (even within one level of government and a single jurisdiction) key responsibilities are split across agencies with competing obligations. They talk of the amount of effort that goes in relatively unproductive administration and in the pursuit of resources to do their work, and bemoan how difficult it is to ‘get the message across’. Such concerns are principally institutional. Many are potentially amenable to institutional reform, but there is lacking a well-researched research agenda around which priorities can be debated and set. One result is the lack of a concentrated ‘attack’ on institutional impediments to more effective weed control.
Aims/objectives
The aim of this report is to provide a well-researched agenda for future weeds research and weed management governance arrangements. It is intended at least to provide a basis for negotiating and setting a research agenda that can be a focus of attention and investment by RIRDC and other funding agencies, or by researchers themselves.

Methods used
Methods used to gather data for this report include: desk research, interviews, and the exercise of judgement as to the likely areas of institutional reform potential that will improve ‘front line’ weed outcomes. Given the number of complex and intersecting variables in weeds governance, no set of proposals can be ‘proven’ to be the correct set of priorities, so our focus has been to balance anticipated research feasibility, potential to have a high ‘front-line’ impact and the likely ease of adoption of resultant conclusions. Whilst to some degree subjective the recommendations are informed by careful research and many years of experience.

The initial ideas were exposed during discussions at the NSW Weeds Forum (2011) and they were workshopped with a number of experts and further exposed at a national weeds strategy meeting. The resultant draft was widely circulated for comment. It was directly emailed to a large list of people active in weeds management, advertised and made available for download on a number of websites.

Results/key findings
The research proposes that there are six goals of an ideal governance system, and that innovation and research to support that innovation is more likely to be valuable if it is directed to these ends.

1. Closed circuit accountability of those who increase the weeds risk.
2. Sufficient resources to manage for ‘market failures’ in weed control.
3. Effective engagement and action across areas of a scale compatible with the particular problem, regardless of tenure.
4. Minimal wasted effort and confusion within the governance system.
5. System-wide good coordination and implementation arrangement.
6. Institutional arrangements for the rapid and comprehensive adoption of good science.

To pursue this framework of goals, five priority research programmes are proposed:
1. Institutional innovations that will enable better integrated ‘front line’ action.
2. Innovations and strategies to increase available front-line human and financial resources.
3. Institutional reforms to streamline the structure of weed governance rules and organisations.
4. Effective institutions to embed scientific continuous improvement in the management of people.
5. Benchmarking and evaluating weeds institutions.

Implications for relevant stakeholders
Current institutional arrangements are far from optimal, in terms of enabling front-line weed control. Problems include complexity, insufficient and unclear accountabilities, and the inability to garner sufficient resources. The research agenda that is proposed aims to assist a variety of key stakeholders to address these issues: helping the government to find ways of reducing the excessive costs in coordination of administration, and in issues of monitoring and reporting; it will help those in the primary industry sector and those concerned with ensuring environmental integrity by finding ways of increasing incentives for private action, and reducing the current complex and cumbersome system which imposing high transaction costs with insufficient offsetting gain.

Recommendations
The study specifies key goals and potential research programmes for institutional innovations in weeds governance.

Communications
The content of the draft report was presented at two forums and widely circulated for comment throughout April 2012.

(PRJ-006906)

“One result is the lack of a concentrated ‘attack’ on institutional impediments to more effective weed control.”
Minor use of chemicals

**Researcher/contact**
Dr. Ian Chivers  
New Rural Industries Australia

**What the report is about**
This project is about assisting the new rural industries of Australia in obtaining minor chemical use permits for the use of herbicides.

**Who is the report targeted at?**
New rural industries of Australia, Australia Pesticides and Veterinary Medicines Authority (APVMA), Research and Development Corporations.

**Where are the relevant industries located in Australia?**
Distributed nationally.

**Background**
Weed control is a major issue for agricultural industries of all sizes and maturity status. For the larger, established industries a wide range of registered herbicides is available and application of the chemical on a weed according to the label is routine. Sadly, for many practitioners in the new and emerging industries, the herbicides that they wish to use for the control of weeds on their crops may not be registered for that use.

For growers in the new and emerging industries the only legal means of using those chemicals is through obtaining an industry-wide permit, known as a Minor Use Permit, for its use under specified conditions. Those permits are issued, when appropriate, by the APVMA and usually apply for a limited period and are subject to regular review.
Aims/objectives

The aim of this project is to assist the plant industry members of NRIA to obtain minor use permits for the use of herbicides in their respective industries by:

- Identifying and prioritising their most important weed problems
- Identifying the most cost effective and practical herbicide solutions for their weed problems
- Determining what information is required to fulfil permit requirements, and obtaining that information
- Submitting permit applications based on identified priorities and other practical considerations, and
- Obtaining some permit approvals.

Methods used

NRIA members and member industries were surveyed as to their major weed problems, the herbicides that were being used and the herbicides that would be preferred to be used in the event of satisfactory resolution of minor use permit issues. That information was collated and brought to a meeting, held in Brisbane on 17 May 2011 which included representatives of NRIA industries, the APVMA, RIRDC, several chemical industry representatives and the facilitators.

Results/key findings

A list of priority chemicals was developed and a set of additional data required in order to complete applications to the APVMA. Subsequent data collection, including the use of international data for comparable industries, allowed for the submission of 11 formal applications across a total of 10 different crop types.

Those applications for 11 herbicides were accepted by the APVMA for evaluation with a review period that will be completed in Spring 2012. The APVMA has three options available to it:

- Reject the application altogether
- Hold the application as pending and require additional testing to occur to provide data that will show whether or not chemical residues are occurring in the food product of the crop
- Accept the application and issue a minor use permit.

While the final decisions of the APVMA have not been made as yet, allowance under the project has been made for field evaluation and residue testing as necessary to progress these applications.

Implications for relevant stakeholders

When completed the minor use permits will allow the legitimate use of the desired herbicides by the relevant industries to proceed and for more effective and efficient chemical use.

(PRJ-006878)
Risk assessment and management of paraquat resistance in the pasture seed industry

Researcher/contact
A/Prof Chris Preston
University of Adelaide

What the report is about
This project aimed to define the extent of paraquat resistant annual ryegrass in pasture seed production and examine farming practices in the industry that may contribute to or reduce the risk of resistance evolution.

Who is the report targeted at?
Growers and consultants in the pasture seed industry, as well as other users of paraquat in the wider agricultural industry.

Where are the relevant industries located in Australia?
Pasture seed is grown throughout Australia for both on-farm use and certified seed sale. South Australia, Victoria and New South Wales have the largest production of leviable pasture seed in Australia. This research was focused in the south-east of South Australia.

Background
The repeated use of paraquat in pasture seed cropping creates a risk for the evolution of resistant weed species. Annual ryegrass (Lolium rigidum Gaud.) is the most significant weed in southern Australian agriculture. Annual ryegrass has well documented wide-spread resistance to glyphosate.

Paraquat is the main alternative non-selective herbicide to glyphosate available and resistance to both glyphosate and paraquat would pose serious weed management problems.

Paraquat is the main alternative non-selective herbicide to glyphosate available and resistance to both glyphosate and paraquat would pose serious weed management problems. Paraquat itself is also an important herbicide for winter cleaning, chemical fallow, double knock and crop topping strategies. The evolution and spread of resistance to paraquat would present a significant issue for pasture seed growers. Assessment of the current level of resistant annual ryegrass to paraquat will give growers and the industry an indication if this is becoming a potential problem for weed management.

Aims/objectives
To identify the extent of paraquat resistance in annual ryegrass in the pasture seed industry. To evaluate farming practices in the pasture seed industry that affect the evolution of paraquat resistance in annual ryegrass.
Methods used
Ryegrass populations were collected with the help of consultants and pasture seed growers from pasture fields in the south-east of South Australia. Plants were tested for resistance to paraquat using the Syngenta QUICK-TEST® method. Plants that survived paraquat application were tested further with dose response experiments. Plants were sprayed with paraquat at the three leaf stage with 100, 200, 400, 800, 1600, 3200 and 6400ml/ha Gramoxone® + 0.2%BS1000.

Results/key findings
A total of 39 ryegrass populations were tested for paraquat resistance and of these nine were found to have varying levels of resistance to paraquat. These findings have confirmed the first documented annual ryegrass populations resistant to paraquat in Australia. Dose response studies showed that one of these populations had resistance at 10 times the field rate of paraquat. Two populations collected were also found to have resistance to both glyphosate and paraquat.

Grower workshops surveying weed management practises provided an overview of farming practices among pasture seed growers in the region. Glyphosate and paraquat are used as an integral part of weed management; however, over 80% of growers surveyed used the range of Group A, L, D, C and M herbicides to control weeds. Paraquat was applied most commonly at one or two applications per year at between 1.5 and 2L/ha. Most growers indicated they used glyphosate and paraquat to target a mixture of small and large weeds, with few targeting mostly large, established weeds. Cultivation, crop topping with both paraquat and glyphosate, and burning stubble were also used regularly for weed management. Growers indicated they perceived most resistance to Group A herbicides, followed by Group M herbicides in weed populations in their paddocks. Almost half of the growers surveyed did not believe they had resistance to paraquat in their paddocks. The repeated use of paraquat over long time periods (>15yrs) in this region has resulted in the evolution of resistance. Growers of clover seed were more likely to report paraquat resistance in barley grass. The repeated use of paraquat over long time periods (>15yrs) in this region has resulted in the evolution of resistance. Growers of clover seed were more likely to report paraquat resistance in volunteer clover species. The evolution of paraquat resistant annual ryegrass in pasture seed cropping has increased risks of potential spread to other systems through contaminated seed stocks. Growers will now need to monitor for possible paraquat resistance in their weed populations and change weed management strategies to manage the problem. Minimising the risk of spread of resistant populations should be considered when hay, seed and equipment are being transported between fields and off-farm. Effective identification of resistant populations by growers, and careful farming practices to minimise spread of resistance will greatly reduce the cost to manage this problem.

Recommendations
The identification of annual ryegrass resistant to paraquat and glyphosate is a threat to the pasture seed industry and to all farmers in Australia. Growers need to implement integrated weed management strategies to reduce resistance evolution. The use of a variety of herbicide groups and mode of action can reduce the selective pressure for resistance to one particular mode of action. Paraquat is the main non-selective alternate to glyphosate; therefore, the management of resistance should be a high priority. The adoption of integrated weed management strategies that minimise the evolution and spread of resistance is essential.

Communications
Proposed journal publication: Morran, S. and Preston, C. Identification of paraquat and glyphosate resistant annual ryegrass in pasture seed production.


Workshop/Seminar ‘Management of weeds with paraquat and glyphosate in pasture seed crops.’ Organised and facilitated by Christopher Preston, Sarah Morran and Jason Sabeeneey. Presented in Naracoorte, South Australia in September 2011.

(PRJ-006912)

“Growers need to implement integrated weed management strategies to reduce resistance evolution”
Tackling Australia’s weed seed liability with the Seed Persistence Tool Kit

Researcher/contact
Dr Rowena Long
University of Western Australia

What the report is about
Understanding seed persistence is critical for the effective management of weeds. Seeds can persist in the soil long after weeds are removed, and act as a reservoir for re-invasion. Yet traditional methods for predicting seed persistence are costly, time-consuming and do not consider the important influence of site and climate factors on seed persistence. This summary reports on a project that aimed to develop a ‘Seed Persistence Tool Kit’ to enable land managers of both natural and agricultural ecosystems to predict how long weed seeds will persist in soils.

Who is the report targeted at?
Land managers and policy officers whose work involves eradicating weeds will benefit from an improved understanding of seed persistence and an improved ability to predict how long seeds of priority weed species will persist in soils at particular locations.

Where are the relevant industries located in Australia?
Natural Resource Management groups nationwide e.g. South Coast NRM (Albany, WA); State and Federal Government Weed Prioritisation groups nationwide – e.g. WA Department of Environment and Conservation (Weed Risk Assessment team, Perth), WA Department of Agriculture and Food (Invasive Species Science team, Perth), Australian Department of Agriculture, Forestry and Fisheries;
Seed and weed scientists nationally and internationally.

Background
A fundamental challenge faced by policy officers and weed managers endeavouring to reduce the impacts of weeds is the uncertainty of how long seeds can survive in soils. Inaccurate estimates of seed persistence are costly: when seed persistence is underestimated, eradication programmes end prematurely and weeds reinvade. Conversely, when seed persistence is overestimated, time, money and labour are wasted in pursuing a problem that no longer exists.

Objectives
The primary objective of this project is to develop a rapid decision-support tool - the ‘Seed Persistence Tool Kit’ - where users can assemble species, seed, site and climate-related information into a check-list that will afford them a more accurate estimate of persistence for both freshly-collected and soil-stored seeds.

Inaccurate estimates of seed persistence are costly: when seed persistence is underestimated, eradication programmes end prematurely and weeds reinvade. Conversely, when seed persistence is overestimated, time, money and labour are wasted in pursuing a problem that no longer exists.
**Methods used**

Seeds of 22 weed species (including 6 environmental, 12 agricultural and 4 roadside weeds) were collected from southwest Western Australia for use in laboratory and field experiments. Seeds were tested for a range of persistence-related properties in the laboratory, including germination responses, response to accelerated ageing and the antimicrobial content of seed coats. Two 5-year seed burial trials were established to verify the accuracy of persistence predictions made from the laboratory studies.

**Implications for relevant stakeholders**

An improved ability to predict seed persistence can assist policy makers and land managers to prioritise species for control, and to estimate the appropriate duration of weed eradication programs.

**Recommendations**

Future research into seed persistence needs to identify which of the many seed, species, soil, site and climate characteristics are key drivers of seed persistence for different weed types and habitats. Long-term field trials are needed to verify the accuracy of predictive models to ensure they are robust and informative for policy makers and land managers.

**Communications**

See table below (PRJ-006918)

<table>
<thead>
<tr>
<th>What</th>
<th>When</th>
<th>Where</th>
<th>Who (audience)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public workshop: “The Seed Persistence Workshop”</td>
<td>17 Nov 2011</td>
<td>The University of Western Australia</td>
<td>Eight local, national and international guest speakers and 45 community members</td>
</tr>
<tr>
<td>Newspaper article: “For how long will seeds be weeds?”</td>
<td>19 Oct 2011</td>
<td>Narramine News &amp; Trangie Advocate</td>
<td>Circulation: 903</td>
</tr>
<tr>
<td>Newspaper article: “Tool kit to tackle weed seed bank”</td>
<td>19 Oct 2011</td>
<td>Esperance Express</td>
<td>Circulation: 3 500</td>
</tr>
<tr>
<td>Newspaper article: “Seed Persistence Tool Kit to help tackle weed seed bank”</td>
<td>19 Oct 2011</td>
<td>Wimmera Advocate</td>
<td>Circulation: 800</td>
</tr>
<tr>
<td>Newspaper article: “Tool kit set to tackle seed persistence”</td>
<td>20 Oct 2011</td>
<td>Farm Weekly</td>
<td>Circulation: 13 522</td>
</tr>
<tr>
<td>Newspaper article: “Weeding out the issue of seed persistence”</td>
<td>22 Oct 2011</td>
<td>Coffs Coast Advocate</td>
<td>Circulation: 30 962</td>
</tr>
<tr>
<td>Newspaper article: “Kit helps to tackle weed seed bank”</td>
<td>25 Oct 2011</td>
<td>South Eastern Times</td>
<td>Circulation: 2 257</td>
</tr>
<tr>
<td>Newsletter article: “How long will weeds survive?”</td>
<td>31 Oct 2011</td>
<td>UWA News</td>
<td>UWA Campuses</td>
</tr>
<tr>
<td>Newspaper article: “Getting rid of weeds”</td>
<td>26 Nov 2011</td>
<td>Bega District News</td>
<td>Circulation: 2 732</td>
</tr>
<tr>
<td>Newspaper article: “Weed seedbank war steps up with ‘toolkit’”</td>
<td>1 Dec 2011</td>
<td>Stock Journal (Adelaide)</td>
<td>Circulation: 13 302</td>
</tr>
<tr>
<td>Radio interview with 2XL - NSW recorded on: 25 April 2012</td>
<td>24 Apr 2012</td>
<td>Cooma Monaro, NSW</td>
<td>Farming community</td>
</tr>
<tr>
<td>Newspaper article: “Weeds need research”</td>
<td>30 Apr 2012</td>
<td>Bairnsdale Advertiser</td>
<td>Circulation: 6 628</td>
</tr>
<tr>
<td>Online article: “Seed funding for seed research” <a href="http://www.psnews.com.au/Page,psn31113.html">http://www.psnews.com.au/Page,psn31113.html</a></td>
<td>1 May 2012</td>
<td>PS Online</td>
<td>Australian Public Service</td>
</tr>
<tr>
<td>Newspaper article: “Toolkit predicts weed seed persistence in soil”</td>
<td>3 May 2012</td>
<td>Stock Journal</td>
<td>Circulation: 13 097</td>
</tr>
</tbody>
</table>
Collation of information on weeds into the National Plant Health Status Report

**Researcher/contact**
Mr Rodney Turner
PHA

**What the report is about**
The document provides a comprehensive report on how weeds are currently managed across Australia, and discusses opportunities for improving response and management arrangements as part of the national biosecurity system.

**Who is the report targeted at?**
The report will be of interest to policy makers, academics, jurisdictions, funding agencies, industry organisations and community groups involved in weed management in Australia.

**Where are the relevant industries located in Australia?**
The report provides a national perspective of weed management in Australia and is of relevance to all agricultural industries.

““As a significant cost burden to industry, there is an opportunity to raise the profile of weeds in industry management and industry biosecurity plans.””

**Background**
Weeds are recognised as a significant threat to primary production, amenity landscapes and the natural environment in Australia. While significant work continues to be undertaken to manage weeds in Australia, including the Australian Weeds Strategy, the Weeds of National Significance (WoNS) and Emergency Invasive Plant programs, a need exists to bring together in one document an overview of the Australian system and to discuss opportunities where weed management, as part of the national biosecurity system, can be improved.

**Aims/objectives**
1. The collection and collation of information on weed management from all key stakeholders in Australia.
2. The analysis of collated information through a review and consultation with selected stakeholders.
3. A published report for use by stakeholders.
4. Publication of summary information from the review of weed management activities in the 2011 version of the National Plant Biosecurity Status Report (NPBSR).
Methods used
1. Identification of data requirements and key stakeholders involved in weed management including those at all levels of government, catchment and Landcare groups, industry & the community.
2. Identification of weed research institutions. Compilation of current and potential future weeds research. Collection and collation of information by Gavan Cattanach (John Thorp Australia) through searches of existing material and literature, surveys sent to key stakeholders and on-line searches and, where necessary, meetings with nominated key stakeholders.
3. Provision of a draft report with an assessment of the stakeholders involved and their current capability and capacity and an estimate of the resources being used on weed management. A discussion of any significant gaps within weed management in Australia.
4. A summary from the Review Report will be used by Plant Health Australia for inclusion in the National Plant Biosecurity Status Report. Plant Health Australia will update this information in future versions of this document.

Results/key findings
1. Weeds are the most significant and costly natural resource management issue facing primary producers. Responsibility for weed management in Australia is spread across a wide range of stakeholders.
2. Community activities are a vital component of Australia’s weeds management system. Opportunities exist for governments to provide strategic guidance and resources that are able to coordinate and motivate community activity at the local level.
3. The WoNS initiative has been successful in coordinating partnerships for strategic action between government, industry and the community.
4. Weeds research is a fundamental component of Australia’s response to and management of weeds. There is a need for commitment to ongoing long term and secure funding for weeds research, in particular support for (longer term) biological control research and implementation programs is required.
5. Analysis suggests that the management of weeds should be recognised as a part of the biosecurity continuum, not just an issue associated with natural resource management.
6. Opportunities exist to improve the national coordination of weed management, in particular emergency response arrangements, for example, with the inclusion of Emergency weeds within the scope of the Emergency Plant Pest Response Deed (EPPRD).
7. As a significant cost burden to industry, there is an opportunity to raise the profile of weeds in industry management and industry biosecurity plans.
8. Many of the findings of the review are supported by the recent National Plant Biosecurity Strategy (NPBS) endorsed by Australian jurisdictions and industries.

Implications for relevant stakeholders
1. An overview of weed management in Australia (including agricultural industries) has been collated into a single document and provides a convenient snapshot of the diversity and extent of weed management in Australia.
2. The review provides a platform for the development of policy and frameworks that enhance the national coordination of weed management.

Recommendations
The conclusions are primarily targeted at policy makers, jurisdictions and funding agencies.

Communication

Weeds research is a fundamental component of Australia’s response to and management of weeds. There is a need for commitment to ongoing long term and secure funding for weeds research, in particular support for (longer term) biological control research and implementation programs is required.
Weed management under dry seeding and permanent residue farming practices

Researcher/contact
Dr David Minkey
WANTFA

What the report is about
This report summarises results from a project that was undertaken in the Western Australian Wheatbelt that investigates herbicide efficacy under dry seeding in the presence of crop residues.

Who is the report targeted at?
The report is targeted at broadacre cropping growers, consultants, agronomists and weed scientists.

Where are the relevant industries located in Australia?
The research was targeted throughout the wheatbelt of W.A., but is of value throughout the southern cropping areas of Australia (S.A., Vic. and southern N.S.W.).

In Western Australia there are 4000 crop growers who produce up to 15 million tonnes of grain annually. The major crops are Wheat, Barley, Canola and Lupin which are exported world wide.

Background
Weed management is the number one issue facing a no tillage farming system across Australia. Not only are growers losing a weed management tool in tillage but the evolution of herbicide resistance has led to limited weed control options. Further to this, no tillage farming enables growers to seed dry, to maximise water use, and so a knock down herbicide pre seeding cannot be used. This leads to an over reliance of pre-emergent herbicides and glyphosate tolerant crops leading to greater pressure on these herbicides for resistance evolution. Another issue facing growers is that permanent stubble retention is seen as an essential component to a good no tillage system, however residue can bound to herbicides preventing them from getting to their target thus reducing efficacy. By overcoming these barriers of weed management to maximise the benefits of a good no tillage system, large productivity gains in the crop growing areas of Western Australia could be achieved and was the focus of this study.

This project investigated, through a series of field applied trials across Western Australia and the use of computer modelling, weed management practices that will enable growers to dry seed and retain stubble.
Aims/objectives
The project objectives were to give growers confidence and best practice weed management options for the practice of ‘dry seeding’ and residue retention by:

1. Demonstrating the benefits of weed management prior to dry seeding.
2. Improving the efficacy of pre-emergent and glyphosate (in a glyphosate tolerant crop) herbicides under dry seeding, high stubble retention systems, and
3. Demonstrating, by the use of computer modelling, the long term economic and weed seed bank benefits of various integrated weed management practices under a dry seeding stubble retention farming system.

Methods used
Field work was set up in Esperance, Mingenew, Cunderdin, and Wickepin that investigated:

1. The benefits of weed management techniques, with a focus on weed seed destruction, leading up to a dry seeding year.
2. The efficacy of pre-emergent herbicides under dry conditions and high stubble loads.
3. The effect of water rates and droplet sizes on the efficacy of pre-emergent herbicides and glyphosate (in a roundup ready crop) under varying stubble loads.

Results/key findings
The major findings of the research were:

1. Under heavier soil types trifluralin may not be properly incorporated in dry soil reducing its efficacy.
2. Sakura® and Boxer Gold® are both suitable pre-emergents for annual ryegrass control in a dry seeding environment, although there are plenty of alternatives.
3. Crop competition can play a key role in both yield and herbicide performance.
4. Weed seed set control at harvest is not a magic bullet in all seasons and must be carefully managed to collect as much weed seed as possible.
5. Delayed seeding with a knockdown leads to better weed control but lower yields.
6. High water volume is essential under high residue conditions especially for less water soluble and mobile herbicides. i.e. more important for trifluralin that Boxer Gold® than Sakura®.
7. While there was a benefit going to bigger droplet sizes it was not as important as factor as water volume.
8. Glyphosate efficacy improved when used post emergent in canola when a higher water volume was used, high rates were used and with split applications.

The research will lead to great weed efficacy for growers who dry seed and retain residues.

Results of the dry seeding research has been incorporated into the weed management model “RIM”, which previously did not have a dry seeding option.

Implications for relevant stakeholders
Industry: Greater weed efficacy and reduced risk when dry seeding.

Communities: More resilient farming communities (drought management).

Policy makers: Awareness of the importance of dry seeding and retaining residue.

Communications
ARTICLES
“Effect of water rate, timing and dose on the effectiveness of Roundup Ready Herbicide in Genetically Modified Roundup Ready Canola”. David Minkey (WANTFA Journal March 2012)

RADIO
ABC Country Hour May, 2012, David Minkey “weed management in dry seeded wheat”.

PRESENTATIONS
Perth Crop Updates, 2012 (Video release, GRDC web site),

(PRJ-006919)
Paterson’s curse as a model to measure impact of climate change on biocontrol for weeds

Researcher/contact
Dr Paul Weston
Charles Sturt University

What the report is about
This report describes the outcomes of a year-long research project designed to assess the spread of the insect biocontrol species that have been released over the past 10-15 years in south eastern Australia for the management of Paterson’s curse, an introduced weed that has spread through much of the southern half of Australia.

Who is the report targeted at?
This report is targeted at district agronomists, crop consultants, researchers, livestock managers, and policy makers who are concerned with the impact of Paterson’s curse on grazing lands and the impact of climate change on Australian agriculture.

Where are the relevant industries located in Australia?
The major industry impacted by the research is the livestock industry, particularly sheep and horse producers. The major sheep production areas in Australia are in New South Wales and Victoria; over half the sheep produced in Australia come from these two states. Anyone with an interest in the health of livestock grazed on lands that serve as sites of potential infestation by Paterson’s curse will benefit from the findings. This includes sheep farmers and graziers, horse producers, agronomists, and policymakers.
Background
Paterson’s curse (Echium plantagineum) is an introduced weed found in vast acreages of southern Australia. The plant produces toxins in the leaves that have adverse health effects on many species of livestock, particularly sheep and horses. Several species of insects have been released for biological control of Paterson’s curse over the past 10-15 years, but the extent to which they have spread beyond the initial sites of introduction is unknown. Because the production of secondary compounds by plants is known to be altered by climate and may impact the ability of biocontrol agents to utilise the plant as a host, it is of great interest to livestock managers and policymakers in southern Australia to know how climate change might alter the chemistry of Paterson’s curse and thus impact the toxicity of the plant and the ability of the insectan biocontrols to effectively manage the weed.

Aims/objectives
The aims of this project were to gauge the spread of biocontrol agents of Paterson’s curse in New South Wales and Victoria from their release sites over the past 15 years and to assess profiles of defensive compounds produced by Paterson’s curse over a wide geographic range.

Methods used
Two surveys were conducted along three east/west transects across New South Wales and Victoria, one in spring and one in early summer of 2011. Paterson’s curse was sampled for the presence of the major insectan biocontrols released by various governmental agencies from the 1990s. In addition, plant tissues were sampled for the presence of naturally occurring defensive compounds produced by the leaves (pyrrolizidine alkaloids) and roots (naphthoquinones).

Results/key findings
The major insectan biocontrol agents were found widely distributed in the sampling area, but the spread from points of introduction varied with species. The most effective biocontrols, the crown and root weevil, were found mainly in the eastern and south eastern limits of the survey area and usually within 100 km of known release sites. The other main biocontrol, a flea beetle, is apparently more mobile and was found more widely spread and considerably further from the sites of introduction, but overall is not as widely established as the weevils. The levels of defensive compounds within the plants sampled were unrelated to the presence or absence of the biocontrols, but did vary with location, tending to be higher in the northern and northwestern limits of the area sampled.

Implications for relevant stakeholders
The results suggest that warming and drying climatic trends observed in Australia in recent years has resulted in increased levels of defensive compounds in Paterson’s curse, which may lead to greater problems for livestock producers if the weed is not effectively managed in the face of a changing climate. Because the spread of the most effective biocontrol agents (the crown and root weevils) seems to be limited, additional releases of these insects over a wider geographic area might result in more effective management of the weed.

Recommendations
The results from this project suggest that climate change may exacerbate problems faced by livestock managers owing to increased presence and toxicity of Paterson’s curse on grazing lands. As a result of this research, the following recommendations are made:

• Consider additional releases of biological control agents for Paterson’s curse, especially the root and crown weevil which are known to be the most effective biocontrols of the weed.

• Manage Paterson’s curse more diligently in grazing lands to limit its spread.

• Expand research into the effect of climate change on production of defensive compounds by Paterson’s curse and other weeds. Experiments under controlled conditions are required to definitively answer the question of whether increased temperature and decreased rainfall will result in increased production of defensive toxins by the plant.

Communications
Two manuscripts are in preparation, one dealing with the distribution of the biocontrol agents in New South Wales and Victoria, and one dealing with the variation in defensive chemistry of Paterson’s curse across the region.

(PRJ-006962)

“...The results from this project suggest that climate change may exacerbate problems faced by livestock managers owing to increased presence and toxicity of Paterson’s curse on grazing lands."
Future proofing the National Post Border Weed Risk Management Protocol

Researcher/contact
Dr Stephen Johnson
NSW Department of Primary Industries

What the report is about
The National Post-Border Weed Risk Management (WRM) Protocol is the key international best-practice guide to the design, implementation and execution of WRM systems. This report outlines the processes undertaken to update, revise and future proof the Protocol.

Who is the report targeted at?
Similar to its predecessor, the National Post-Border Weed Risk Management (WRM) Protocol (HB 294:2006), the revised protocol will inform decisions made by: Ministers (Australian, State, Territory); Australian State and Territory Natural Resource Management, Resource Management and Economic Development Departments; Policy advisors and Policy makers (Australian, State, Territory); Local Governments; Natural Resource Management Boards; Industry and Industry Representative Groups; Non-government organisations, Weed researchers, Funding bodies and Private landholders.

Where are the relevant industries located in Australia?
Throughout Australia.

Background
The National Post-Border Weed Risk Management (WRM) Protocol (HB 294:2006) was published by Standards Australia, Standards New Zealand and the Cooperative Research Centre (CRC) for Australian Weed Management in 2006. Since its publication the Post-Border (PB) WRM Protocol has been used to guide the development and implementation of three PB WRM systems across Australia (for the Northern Territory, New South Wales and the current Future Farm Industries CRC based in Western Australia). With some modifications, it has been adopted internationally by the Food and Agriculture Organisation of the United Nations. In the same year (2006) the National Weed Risk Management Forum (the WRM Forum) was formed as part of the Weed CRC’s Risk Management program. In customising the 2006 Protocol for use in different jurisdictions and its application internationally, a number of elements that required revision and refinement were identified by users and stakeholders. In 2008 the WRM Forum commenced reviewing the 2006 protocol at a workshop held in Adelaide. The workshop identified a number of areas in the 2006 protocol that required refinement and areas that were not addressed in drafting of the 2006 protocol.
Aims/objectives
This project aimed to completely update and future proof the 2006 protocol. The following (summarised) objectives were addressed with respect to the National Post-Border Weed Risk Management (WRM) Protocol (HB 294:2006): review previously identified areas requiring revision and identify others; review literature and update various sections including literature sources, pre- and post-border WRM systems, risk management standards and handbooks, measures of reliability/uncertainty and the management of contentious plants; a new section on translating WRM results into policy and management responses; and investigations of the addition of new questions, for example on weediness history, climate change, cultural impact, economic costs and aquatic plant risk assessment.

Methods used
Guided by and with the assistance of the WRM Forum and Expert Advisors, the project officer reviewed WRM and Weed Risk Assessment (WRA) literature, edited the 2006 Protocol including the revision of supplementary material and has prepared a draft revision, informed by the outcomes of a workshop and various communications. The draft revision needs to be circulated to the project team for final review before it is submitted for professional peer review. Once that process is complete, the document will need to go through Standards Australia processes prior to the document being published by them.

Results/key findings
The National Post-Border Weed Risk Management Protocol continues to be international best practice. Among the various benefits that have already accrued to the following parties from work on the revised handbook: Australian scientists continue to lead the international WRM research and implementation field and will publish improvements to the 2006 Protocol; State and Territory governments have improved their WRM capacity affecting positive economic and social benefits, for example there have been more timely detections, containment and eradications of weed species in New South Wales (NSW) through applying improved processes in the revised handbook, resulting in decreased long term management costs to the Australian community; similarly, environmental values have been enhanced and further protected by the same, for example the NSW Office of Environment and Heritage have used the revised principles to inform their management responses to high priority (restricted) weeds thus protecting numerous species that are threatened as well as endangered ecological communities. It is likely that this situation has been repeated throughout Australia.

Implications for relevant stakeholders
The National Post-Border Weed Risk Management Protocol needs to be updated at five yearly intervals to ensure that it remains international best practice, and implementation and communication of the updated guide needs to continue.

Recommendations
The following recommendation is for Standards Australia, the Australian, State and territory governments to consider: that the National Post-Border Weed Risk Management Protocol continue to be updated at five yearly intervals should new research become available to ensure that it remains international best practice.

Communications
In addition to communications outlined in progress reports, the following publications were produced:


Anon. (2012). Revised handbook. National Post-Border Weed Risk Management Protocol (Standards Australia/RIRDC) - draft revision (before final review by the project team) sent to RIRDC 22 May. The revised handbook is subsequently to be sent for professional peer review and then to Standards Australia (hence changes will be made to this draft revision). The project leader is happy to continue to drive this process, and to supply more up-to-date drafts as these processes occur.

(PRJ-006963)

that the National Post-Border Weed Risk Management Protocol continue to be updated at five yearly intervals should new research become available to ensure that it remains international best practice.
Suppressive plants as part of an integrated management program for parthenium weed

Researcher/contact
Prof Stephen Adkins
University of Queensland

What the report is about
This study selected, and then field appraised, a series of pasture plants that could suppress the growth of the invasive alien species, parthenium weed. Since this weed is imposing significant production losses to the northern beef industry and is presently inadequately managed, this new management component will add to those already in use, improving sustainable management for this weed.

Who is the report targeted at?
Pastoralists, land managers, natural resource management bodies, policy makers and other related stake holders in the northern rangelands should read this report. The main beneficiaries of this research are the livestock producers of central and south west Queensland.

Where are the relevant industries located in Australia?
The Australian beef industry is predominantly located in northern inland regions of Australia, in areas from the Gulf country in the Northern Territory and Queensland through inland New South Wales and into northern Victoria. The Australian beef industry employs a total of around 34,000 people over 32,000 properties and is worth $7 billion per annum to the Australian economy. The national benefits will be towards creating an improved integrated weed management approach for this serious alien invasive species in northern Australia, notably the central and south west regions of Queensland. For the livestock producers living in already infested lands, this research will help to contain and prevent the further spread of the weed as well as reducing the impacts of the present infestations.

Background
Parthenium weed (Parthenium hysterophorus L.) is a major alien invasive species causing serious economic, health and environmental problems to north eastern Australia. According to Adamson (1996), in central Queensland alone, pastoralists lose ca. $95 million per year due to reductions in beef production due to this weed alone. To date, the main efforts to manage parthenium weed have been through a biological control program using introduced insects and plant pathogens which has provided partial management. Hence, supplementary management strategies are essential.

Aims/objectives
The objectives of the project were to (i) identify through the screening of pasture plants those that were thought to be capable of suppressing parthenium weed growth in the field, (ii) undertake field trials on these potentially growth-suppressing plants in climatically different regions of Queensland, (iii) to use the data from the field performance and that of new plant selections to create sowing mixes for the suppression of weed growth under field conditions, and to (iv) undertake trials using these species mixtures to investigate their effects upon parthenium weed growth, their ability to produce fodder and their effects upon the native community biodiversity.
Methods used

Germplasm screening: Certain morphological and physiological characters of pasture plants that have been found to correlate with their suppressive ability against parthenium weed (Khan, 2011) were used as a tool for screening a wide range of germplasm (native and introduced; buffel grass being used as a common standard between sites and also to provide an historical perspective to past pastoral practices) to identify further candidate species for field testing under a range of environmental conditions.

Field trials: The selected pasture species were evaluated in field trials conducted at two climatically different regions, at Mungallala, south west Queensland and at Injune, central west Queensland. The effectiveness of the selected plants in suppressing parthenium weed growth was determined by studying the changes in biomass and density of the weed as well as their own biomass over a 120 day period.

Grazing trials: A paddock scale simulated grazing trial was undertaken using two mixtures of selected pasture plants to investigate their effect on the suppression of parthenium weed growth at Kilcoy, south east Queensland. The effectiveness of the mixture in suppressing parthenium weed growth and their response to simulated grazing was monitored over a 90 day period, as was their impact upon plant community biodiversity.

Results/key findings

Eleven pasture species (both native and introduced) were selected on the basis of their predicted or known suppressive ability, recommendations from experts (UQ and NRM) and their suitability to the environmental conditions of the trial sites (determined using the ‘pasture picker’ web resource). Out of the seven species tested at Mungallala, four (tall finger grass, Rhodes grass, Queensland blue grass and Wynn cassia) were found to be strongly suppressive of weed growth (growth suppressed by >80%). It was interesting to note that Queensland blue grass being native grass species not only strongly suppressed the growth of parthenium weed but also ranked as the highest fodder biomass producing species of all species tested at that site. Out of seven species tested at Injune, only tall finger grass was found to be strongly suppressive (growth suppressed by >80%) followed by butterfly pea (66%) buffel grass (65%) and Wynn cassia (61%). The two native species tested gave only weak suppression or failed to establish. At this site, the best fodder biomass was produced by buffel grass followed by butterfly pea. From mixture one (Rhodes grass, creeping blue grass, butterfly pea, green panic and bull Mitchell grass) tested at Kilcoy, the major contribution to forage production was made by Rhodes grass, butterfly pea and green panic (with establishment rates of 3.48, 2.41 and 2.33 plants m-2, respectively). From mixture two (forest blue grass, red grass, Queensland blue grass, atro, buffel grass and hoop Mitchell grass), the major contributions to forage production was made by atro and buffel grass (with establishment rates of 4.04 and 2.81 plants m-2, respectively). Ninety days after sowing, weed abundance was reduced more under the second pasture mixture than the first, however, the experiment was affected by a significant infestation of Zygogramma bicolorata, an already released biological control agent which was responsible alone for significant reductions in the weeds biomass. The reduction of parthenium weed abundance at the Kilcoy site has not yet translated into an improvement in pasture community species richness, which is expected to be detected in future years. The significance of this study is that parthenium weed can now be better managed, in a sustainable fashion, using valuable fodder-producing plants, in a wide range of habitats.

Implications for relevant stakeholders

The implications are that cost effective improvements are now available to supplement the integrated management program for parthenium weed utilizing beneficial suppressive fodder plants.

Recommendations

The recommendation is that beef pasture producers develop a better sustainable management program for this weed using suppressive plants as part of an integrated management program and policy makers incorporate the new information into best management practice manuals for parthenium weed.

Communications

Workshops were held in Brisbane with the National Parthenium Weed Management Group and guests in June 2011 and in Cairns with the International Parthenium Weed Network in September 2011. The results of these findings have been presented at the 23rd Asian Pacific Weed Science Society meeting in Cairns, September 2011 and will be presented at the International Weed Science Congress in Hangzhou, China in June 2012. One publication entitled ‘A glasshouse study examining the suppressive ability and traits of pasture plants on the growth of parthenium weed’ is planned for the Weed Research journal. Other publications on the field component are expected to follow.

(PRJ-006971)

“...The significance of this study is that parthenium weed can now be better managed, in a sustainable fashion, using valuable fodder-producing plants, in a wide range of habitats.”
Diagnostic tools for rapid detection of non-target-site metabolism-based herbicide resistance

**Researcher/contact**
Dr Qin Yu  
University of Western Australia

**What the report is about?**
Using a non-radioactive method to detect enhanced metabolism-based herbicide resistance.

**Who is the report targeted at?**
The report is targeted at weed research scientists, agronomists, extensionists and farmers.

**Where are the relevant industries located in Australia?**
The Grains Research and Development Corporation (GRDC) and agrochemical companies will benefit from this research.

**Background**
Australia has the largest herbicide resistance problem in the world due to evolution of resistance in weeds. Herbicide-resistant weeds pose a great risk to crop productivity and sustainability. At greatest risk is the $10 billion p.a. export grains industry. The GRDC conservatively estimates herbicide resistance is currently costing $200 million p.a. The greatest challenge posed by herbicide resistant weeds is the accumulation in individuals of many resistance mechanisms, both target-site and non-target-site. *L. rigidum* or other weeds possessing multiple herbicide resistance, especially non-target-site enhanced P450 metabolism of many herbicides are more threatening and difficult to control chemically, because P450-based resistance can occur across several herbicide modes of action and can extend to new herbicide discoveries. While target-site gene mutations that endow herbicide resistance can be precisely identified and rapidly diagnosed using PCR-based molecular markers, non-target-site metabolism based herbicide resistance is relatively difficult to positively diagnose. Current diagnostics tests for non-target site enhanced metabolic resistance are mostly HPLC (High Performance Liquid Chromatography) based involving the use of radioactive-labelled herbicides and are often limited by the availability of expensive 14C-labelled herbicides and difficulty to detect low level herbicide metabolism.
Research Aims/objectives

Liquid Chromatograph-Mass Spectroscopy (LC-MS) is a highly sensitive analytical technique and is increasingly accessible. The objective of this proposed project is to develop a LC-MS method to replace current 14C methods for qualitative and quantitative analysis of major herbicide metabolism in important resistant Australian weed species (e.g., annual ryegrass, wild oat). The final goal of this project is to establish a quick and simple diagnostic tool to determine and monitor the extent and frequency of enhanced herbicide metabolism based resistance in Australian major weeds. Australian grain industries and crop growers will benefit from the research.

Methods used

Ultra performance liquid chromatography-mass spectrometry (UPLC-MS, or alternatively LC-MS) was used in this project. For details refer to manuscripts.

Results/key findings /Outcomes

In this project we developed a simple LC-MS protocol to identify the herbicide active ingredient diclofop acid and quantify its tissue concentration. Using this method, we measured tissue concentration of diclofop acid in several diclofop resistant and susceptible wild oat and annual ryegrass samples and the results were found to be consistent with results obtained using the C14-HPLC method. We established that LC-MS method can replace C14-method to identify diclofop acid and monitor its level in plant tissue without much sample preparation. We proved that compared to the C14-HPLC, LC-MS is more sensitive and accurate to identify and quantify herbicidal ingredients and allows for mimicking field herbicide application situation, and the results were reproducible. We established that the LC-MS method is reliable for quantification of tissue diclofop acid level with minimum sample preparation and therefore, can be used as a diagnostic tool for diclofop metabolism in major grass weeds ryegrass and wild oat. Using the method established in this project we screened over 33 field-collected diclofop resistant ryegrass populations (resistant frequency from high, medium to low). We found that 70% of populations have the potential of enhanced herbicide metabolism and 61% population have both target-site (ACCase gene mutations) and non-target-site metabolic resistance. Since diagnosis of enhanced metabolism is often based on the absence of target site mutations in individual plants yet surviving herbicide treatment, this is the first case of positive diagnosis of enhanced herbicide metabolism in heterogeneous field populations.

Implications for relevant stakeholders

Multiple resistance (metabolic plus target site-based resistance) will greatly reduce herbicide options. It also compromises the effectiveness of herbicide sequences, mixtures, or rotations in delaying resistance evolution. This is important for growers, grain industry and herbicide companies, as eventually multiple resistance will drive herbicides into redundancy.

Recommendations

Australian major weed Lolium and Avena have evolved enhanced metabolism based herbicide resistance; metabolisable herbicides must be used cautiously. Herbicides that are not readily metabolised in weeds are less likely to select for metabolic resistance and therefore, are important tools for managing metabolic resistance. Integrated weed management should be implemented to reduce reliance on chemical weed control.

Communications/Publications

The information obtained will be communicated in Australian Herbicide Resistance Initiative (AHRI) website, in talks and seminar, in conference such as Crop Updates. The results will be published in peer-reviewed scientific journals. So far, two manuscripts (one on enhanced diclofop metabolism in wild oat, and one in ryegrass) have been completed and under internal review for submission, and the third manuscript on metabolic resistance screening of WA diclofop resistant populations will be prepared once the results are further confirmed.

Muhammad Saiful Ahmad-Hamdani, Qin Yu, Heping Han, Gregory R. Cawthray, Shao F. Wang, and Stephen B. Powles Herbicide resistance endowed by enhanced rates of herbicide metabolism in wild oat (Avena spp.) (To be Submitted)

(PRJ-0067098)
Tools for adoption of optimal weed management strategies in cropping systems

Researcher/contact
Dr Michael Robertson
CSIRO

What the report is about
Understanding the impacts of weeds and the opportunities for new weed management approaches requires the ability to analyse weed dynamics across soils and seasons. This project enhanced the capability of Australia’s researchers and advisors to deal with weeds in cropping systems by developing new modules for key weeds of cropping systems, developing and applying herbicide resistance models to various resistance evolution scenarios, and defined the needs, preferences and characteristics of users of computer-based decision support systems for weeds in cropping systems.

Who is the report targeted at?
Researchers who wish to analyse the consequences of managing weeds in cropping systems, and advisors and extensionists who use computer-based decision support systems for weed management advice.

Where are the relevant industries located in Australia?
The project addressed the broadacre cropping regions in southern Australia, based on cereals, legumes and oilseeds. This area covers approximately 20 million hectares of cropping land in southern Australia.

Background
Systems simulation is now a well developed capability in broadacre agriculture in Australia, being used by researchers to enhance field experiments and by growers and advisors in the form of computer-based decision support tools (e.g. Yield Prophet). Despite this, the capacity of APSIM, Australia’s leading agricultural systems modelling platform, to model weeds in competition with crops is limited. Early attempts established a basic set of generic parameters for simulating weeds, but this has received limited testing and there is no means to deal realistically with the population dynamics of weed seeds and plants. This project provides that sorely needed capability and enhance the ability of the research community and industry to deal with weeds in broadacre cropping systems.

Resistance to herbicides is a well documented threat to the ongoing viability of crop production in Australia. A complex interplay of factors drives the evolution of resistance in weed populations and there is an emerging well-founded understanding of the role of multiple genes, season, selection pressure and management intervention. This knowledge has yet to be combined in models that link with variability in crop and weed seed production to devise management strategies that minimise the development of resistance. This project will make significant strides towards this goal and test this new capability with decision makers in workshop settings.

Models have played an important role in weed management research but their use as a decision support tool by advisors and farmers has been far more limited. There is a major opportunity to identify what the key characteristics and output of an influential weed management decision support tool are from the end-user perspective. This will inform future decision support development and delivery to agronomists, growers and consultants. It will guide how models developed primarily for research may be adapted and delivered as end-user decision-support tools and it will inform the potential strategic development of tools specifically for industry end-users.

To further inform the development of strategies for improved weed management there is a need to identify where there is the greatest opportunity for new research information and extension strategies to have highest impact. Given the large diversity in farming systems and weed issues across Australian agro-ecological regions it will be important to identify both common and situation-specific opportunities to improve weed management decisions and adoption. The factors associated with the adoption of various components of integrated weed management have not been documented across diverse agricultural regions in Australia and would help targeting of extension and education programs. The factors associated with the adoption of new technologies and management practices by farmers include characteristics of the technologies themselves, characteristics of potential adopters and potential learning opportunities where research information and extension can help to reduce uncertainty and demonstrate relative advantage.

Aims/objectives
- To develop an enhanced capability to simulate the production and environmental impacts of weeds in cropping systems
- To determine the potential role that decision support systems can have in increasing adoption of better practices and the extent of adoption by grain growers of integrated weed management
- To identify optimal management strategies for management of herbicide resistance in cropping systems

Methods used
The project was comprised of three parts:

1. Derivation of weed parameters from APSIM and improved approaches for simulating population dynamics and competition. We produced new APSIM modules for radish and annual ryegrass, and improved systems management templates and user documentation for APSIM users.
2. Linking resistance models and production models so that resistance evolution scenarios under climate variability and different tillage systems can be explored. Scenarios included various forms of integrated weed management, selection pressure, frequencies of resistance genes in weed populations and agro-ecological environments.
3. Trialling decision support models with consultants and leading growers in workshops across the cropping zone where existing and new modelling tools will be used with groups to explore the consequences of various integrated weed management options. The value of the tools and preferred characteristics of decision support systems was assessed by choice modelling.

“The project improved the understanding of economic and environmental impacts of weeds of croplands.”

Results/key findings

The project:

1. Developed new modules for radish and ryegrass, so that the impacts and management of these key weeds in cropping systems can be addressed by users of the APSIM model. We have also made it easier for APSIM users to design simulations with a range of weed management options.

2. Developed and applied herbicide resistance models to various resistance evolution scenarios. It was showed that ecological traits have a strong influence on the evolution of resistance, and that this influence depends significantly on genetics and herbicide usage pattern. Also, no-tillage systems do not increase the rate at which resistance evolves, and that strategic use of soil inversion could delay resistance by burying resistant seed and also by bringing susceptible seed back to the surface. Efficacy of the tillage strategy is affected by underlying genetics, dormancy and mortality rates to some degree. In another application, we found that rotating all available herbicides can extend weed management sustainability compared to using herbicides one by one until they are no longer effective, but the difference is very small, and the particular rotation strategy used has very little overall effect.

3. Defined the needs, preferences and characteristics of users of computer-based decision support systems for weeds in cropping systems. It was found that advisors want a tool that can deliver a prediction of the following year’s weed density if the weeds in the current crop are allowed to set seed was most highly valued. However, a range of herbicide resistance and weed population prediction tools were also valued highly. Advisors placed a very high value on decision support tools that required three or less hours of input time compared to those that were more time demanding. The ability to produce predictions for particular individual fields rather than just more generic district representations was not valued highly by private sector advisors. Two types of advisors were identified based on their preferences for decision support tool attributes.

Implications for relevant stakeholders

Researchers who wish to use weed simulation models in their research. They now have enhanced capability, particularly for examining the effects of weeds on resource availability in cropping systems.

Extensionists who provide advice to farmers on weed management now have options on the use of strategic tillage and herbicide rotation to limit the development of resistance to herbicide (see above for detail).

Developers and promoters of decision support systems

The project improved the understanding of economic and environmental impacts of weeds of croplands through synthesis of existing knowledge into industry modelling tools. This increased understanding will both improve research efficiency and also industry adoption of improved practices.

Recommendations

Our recommendations are targeted at researchers who wish to analyse the consequences of managing weeds in cropping systems, and advisors and extensionists who use computer-based decision support systems for weed management advice.

Communications

JOURNAL AND CONFERENCE PAPERS

Kragt ME, Llewellyn RS improving the design of weed decision support tools. Journal yet to be determined.


Flower KC, Renton M Strategic mouldboard ploughing in no-till systems reduces the risk of herbicide resistance development in weeds. Journal yet to be determined.

Renton M, Thornby D, Gill G. Ecological functional traits affect the risk of a weed species developing resistance to herbicides. Journal yet to be determined.


PROJECT WORKSHOPS

Mon 31st Oct, 2011 Clare SA Country Club, White Hut Rd (23 participants)

Tue 1st Nov, 2011 Adelaide, SA Gil Langley Room, Adelaide Oval, North Adelaide (19 participants)

Wed 2nd Nov, 2011 Horsham Vic Horsham RSL, McLachlan Street (32 participants)

Thu 3rd Nov, 2011 Skipton Vic Football Club, Smythe Street (15 participants)

Fri 4th Nov, 2011 Bendigo Vic Quality Resort All Seasons, McIvor Rd (16 participants)

Dubbo NSW, Cascades Motor Inn. 22 November, 14 participants

Toowoomba Qld, DEEDI Conference Centre, Tor St. 23 November, (7 participants)

Perth WA, University of Western Australia. 30 November, (9 participants)

(PRJ-006984)
Integrated weed management in vegetable crops: 
Gap analysis and RD&E plan

Researcher/contact
Ms Lauren Thompson
Scholefield Robinson Horticultural Services

What the report is about
This report summarises the findings of the Gap Analysis phase of the project at the time the project ended. It was decided by RIRDC, and agreed by Scholefield Robinson Horticultural Services, that the project should not proceed to the phase involving development of an Integrated Weed Management (IWM) RD&E Plan.

Who is the report targeted at?
The Gap Analysis Report, along with other recommended documents, may provide a foundation for improved targeting of weeds RD&E investment by AUSVEG (the national peak industry body representing growers of more than 100 vegetable commodities) and Horticulture Australia Ltd (HAL).

Where are the relevant industries located in Australia?
According to an ABS report, in 2006/07, across all the States there were approximately 6,550 businesses growing vegetables for human consumption on 125,000 hectares. The Northern Territory also has a small area of production that is slowly increasing. Statistical divisions having at least 6,000 hectares of production in that year were West Moreton (Qld), Wide Bay-Burnett (Qld), Mackay (Qld), Melbourne (Vic), Murrumbidgee (NSW), Murray Lands (SA), Mersey-Lyell (Tas) and Northern (Tas). In WA, the South West statistical division had the largest area of production at 3,464 ha. There are also significant numbers of growers in peri-urban production areas in the vicinity of Melbourne, Sydney, Adelaide, Brisbane and Perth.

Vegetables are predominantly produced for the domestic fresh market. Specific vegetables are grown for and sold to processors and small amounts of particular vegetable commodities are exported.
Background
At the time the proposal for this project was submitted to RIRDC, it appeared that Integrated Pest Management (IPM) was a high priority for the vegetable industry. A HAL-facilitated project, VGO919, National Vegetable IPM Coordinator (funded by the National Vegetable R&D Levy with matching Federal Government funds) was underway and a key output of this project was the “Vegetable Integrated Crop Protection RD&E Plan, 2011-2015”. This consisted of an ‘over-arching’ plan involving coordination requirements as well as the requirement for specific ‘Program Plans’ to be developed, including an IWM RD&E Plan.

Aims/objectives
The stated aim of this RIRDC project was to develop the IWM RD&E Plan that would become part of the Vegetable Integrated Crop Protection RD&E Plan. The intended objectives were: improved targeting of investment into weeds RD&E; improved availability of information, tools and technology to assist growers with implementing integrated weed management approaches; reduced application of herbicides and an increase in the use of non-chemical approaches to weed management; and improved profitability for vegetable growing businesses and associated environmental and social benefits for the regions and communities in which they operate.

Producers of field-grown vegetables would be the primary beneficiaries of IWM-related RD&E initiatives.

Methods used
The RD&E Plan was to be based on the findings from the gap analysis phase of the project. At the time of submission of the Gap Analysis Report, accomplishments in the gap analysis phase included a review of literature, including Final Reports from HAL-facilitated projects related to IWM in vegetable crops, preparations for and the start of stakeholder consultations, and a review of extension resources for use by consultants, advisors and growers in Australia.

Results/key findings
Stakeholder consultations to date indicate that the vast majority of producers of field-grown vegetable crops are using practices considered to be at the ‘Low or Basic’ end of a spectrum of practices described in an ‘IWM Continuum’ document produced as part of the project. Some growers are using ‘Medium IWM’ practices and very few are using ‘High IWM’ practices. Growers using High IWM practices and consultants and research/extension personnel involved in IWM expressed support for using R&D funds to investigate new IWM practices and technologies. However, growers using ‘Low or Basic IWM’ practices who were involved in the consultations considered many of the new practices/technologies to only apply to organic production.

Implications for relevant stakeholders
AUSVEG and HAL were in the process of finalising a Vegetable Industry Strategic Investment Plan (SIP) that would guide investment of the National Vegetable R&D Levy for the next five years. IPM, which includes IWM, was rated as having a “Low” priority in the most recent draft of the SIP, which was issued in December 2011. It is likely IPM/IWM will continue to have a Low priority in the final SIP, which will be released in May 2012. It may be the case that IWM RD&E will not become an important priority for the Australian vegetable industry unless/until herbicide resistance becomes a widespread problem or an important herbicide is removed from the market.

Recommendations
The Gap Analysis Report from this project, a recently completed Final Report from a HAL project (VGI0048) conducted by Dr Brian Sindel of UNE on sustainable weed control in cucurbit crops, and the outputs of a RIRDC project conducted by Roslyn Prinsley on behalf of New Rural Industries Australia (NRIA), which include a ‘non-chemical weed management RD&E plan’ and project briefs associated with the plan, are recommended as sound background documents that could assist AUSVEG and HAL with formulating weed management RD&E priorities at some point in the future.

(PRJ-007070)
What the report is about
Maintaining freedom from weed competition is essential in attaining full yield potential of rice crops. Ponding is an important cultural technique for suppressing the growth of highly competitive grass weeds. Aerobic rice culture (ie: with long periods of no ponding) can improve water-use efficiency; however it provides an enhanced environment for weed growth. This report details results of field investigations conducted to improve weed control in aerobic drill sown rice crops.

Who is the report targeted at?
Ricegrowers and agronomists who are actively seeking methods of reliable aerobic rice production.

Where are the relevant industries located in Australia?
Most rice production in Australia occurs in the Riverina of NSW and northern Victoria, coupled with small pockets in northern Australia around the Burdekin river (Queensland) and Kununurra (Western Australia). Approximately 1400 rice growers plant approximately 100,000ha of rice per annum when irrigation water is available. Average yields are high (approximately 8-12 tonne/ha) with the crop sold domestically and internationally by the Sunrice company based in Leeton, NSW.

Background
Weed control in rice has been practiced continuously for thousands of years by an integrated approach of ploughing, puddling, transplanting in rows and hand pulling. Transplanting of rice is uneconomic in most advanced economies because of labour shortages and cost constraints, thus direct seeding is practiced. Almost all direct seeded rice is highly dependent upon effective herbicides to render the crop free of weed competition. Over-reliance on any one product can rapidly lead to selection of resistant weed biotypes that may render multiple herbicide products ineffective. This occurred rapidly in the 1990’s with bensulfuron in Australia and led to new strategies to defer or prevent herbicide resistance development.

Improving water use efficiency in rice (eg: productivity per megalitre) has long been a goal of Australian rice producers. This can be achieved by higher yields per hectare (for a given volume of water consumed) or else by reducing water inputs per hectare. The latter means has delivered productivity improvements by delaying permanent inundation late into the tillering phase of crop phenology (termed “aerobic rice”). Delaying permanent irrigation results in more favourable environments for grass weed competition (aerobic soil) and so places added challenges on weed control practices.

Echinochloa crus galli (barnyard grass) and Leptochloa fusca (silvertop grass) are two annual grass weeds that prove highly competitive with drill seeded (aerobic) rice in Australia. Additionally Cyperus difformis (dirty Dora); an annual sedge species may prove competitive if the soil surface remains moist for a prolonged period during crop establishment.
The newly adopted commercial standard of clomazone plus pendimethalin applied PSPE (plus either paraquat or glyphosate) achieved the most consistent and highest levels of barnyard grass control in all experiments and the highest grain yields and water use efficiency.

**Aims/objectives**
This project aimed to improve options for effective weed control in aerobic rice crops managed with delayed permanent irrigation for the benefit of Australian rice growers.

**Methods used**
Nine replicated field trials were established in drill seeded aerobic rice near Jerilderie, NSW, Finley, NSW and Cobram, Victoria. The purpose of these trials was to identify new and improved herbicide treatments to prevent weed competition in aerobic rice. Treatments under evaluation included prosulfocarb, isoxaflutole, prometryne and a micro-encapsulated formulation of pendimethalin (all applied post sowing, pre-emergence, PSPE) and post emergence treatments including propanil, pendimethalin, clomazone, thiobencarb, cyhalofop-butyl and profoxydim.

**Results/key findings**
Isoxaflutole applied PSPE proved excessively phytotoxic to drill sown rice. Prometryne applied PSPE failed to effectively control barnyard grass, although crop safety appeared adequate. Prosulfocarb demonstrated only moderate barnyard grass control and adequate crop safety applied PSPE.

Micro-encapsulated pendimethalin gave slightly improved levels of residual barnyard grass control over equivalent rates of the emulsifiable concentrate formulation, warranting further evaluation as a PSPE treatment. Most post emergent treatments of propanil, thiobencarb, clomazone or pendimethalin did not adequately control barnyard grass. Clomazone demonstrated some minor incompatibility with cyhalofop-butyl and profoxydim.

The newly adopted commercial standard of clomazone plus pendimethalin applied PSPE (plus either paraquat or glyphosate) achieved the most consistent and highest levels of barnyard grass control in all experiments and the highest grain yields and water use efficiency.

**Implications for relevant stakeholders**
Depending upon cultural techniques alone (such as crop rotations, clean seed, dense plant stands and even floodwater levels) cannot ensure production of weed free aerobic rice crops. Post sowing, pre-emergence treatments of clomazone plus pendimethalin (plus paraquat or glyphosate) were demonstrated as the most reliable method of attaining weed free aerobic rice crops. This enables Australian rice growers to dependably establish aerobic crops with confidence in seasons when irrigation water is limited. By adopting the clomazone plus pendimethalin treatment, growers concurrently deliver two alternate modes of herbicidal action to the same cohort of weeds, thus achieving a “double knock” in order to defer the development of herbicide-resistance in their weed populations.

Rice marketers and water policy makers can be assured that these findings justify confidence that rice production can be maintained in seasons when irrigation water supply is doubtful in spring when rice crops must be established on-time to ensure full yield potential is achieved.

**Recommendations**
Pendimethalin plus clomazone mixtures applied post sowing, pre-emergence should remain the preferred herbicide treatment for drill seeded rice produced in southern Australia.

Searching and screening for selective residual herbicides for drill sown aerobic rice ought to continue with a view to offering rotational options to clomazone and pendimethalin.

**Communications**
Presentations were made to all pre-season rice growers meetings, three field days organised and two extension articles prepared for the IREC newsletter.

(PRJ-007074)
Alternative approaches to chemical weed control measures in new industries

**Researcher/contact**
Dr Ian Chivers
New Rural Industries Australia

**What the report is about**
This Plan aims to ensure that Australian rural industries are equipped with the knowledge, resources and technology to successfully prevent, mitigate or adapt to weeds in our agricultural systems, ecosystems and landscapes through alternatives to traditional herbicide use.

**Who is the report targeted at?**
This report is aimed at the new and emerging rural industries, both plant and animal based, that are producing novel products and often using new techniques.

**Where are the relevant industries located in Australia?**
These industries cover a wide climatic and geographic range – including tropical, sub-tropical, and temperate climates, as well as a diversity of crops (annual and perennial) and livestock.

**Background**
Invasive plants are cited as the most persistent impediment to increased production in the cropping industry across Australia. However, we know that prolonged usage of certain herbicides can jeopardize environmental quality and potentially impact human health. Similarly, increased awareness of food safety and environmental issues has led to an increased demand for food products with lower herbicide residues and consequently, production systems which minimise the use of pesticides. These trends have stimulated interest by producers in both new and traditional industries in alternative non-chemical weed control methods. To minimize the potential for damage, effective weed management systems that are less reliant on herbicides are needed.

“A comprehensive R&D Plan has been developed which highlighted several specific areas of necessary research.”
Aims/objectives
This project aimed to develop a comprehensive R&D Plan that would establish what work is required in order to contribute new quantifiable information to assist in developing a set of economically viable, alternative weed control methods.

Methods used
Representatives of New Rural Industries Australia (NRIA) coordinated a workshop involving participants from the Organic Farmers Association, several Universities, some State Departments of Primary Industry and a wide range of crop managers. Input both before the workshop and following it, contributed to developing a comprehensive R&D Plan.

Results/key findings
A comprehensive R&D Plan was developed which highlighted several specific areas of necessary research. These were:

1. To determine, analyse and communicate the latest information on non-chemical weed management from research results and practitioner experience and experimentation;
2. To examine the use of natural chemicals to control weeds;
3. To investigate the use of farming systems, improved crops and crop rotations to control weeds;
4. To compare the use of physical weed control practices (such as flame, steam and GPS/robotics) with traditional chemical weed control;
5. To investigate alternative options to synthetic herbicides for controlling weed seed banks.

Implications for relevant stakeholders
When sufficient funding is available, this plan can be brought forward and immediately adopted as a framework within which to investigate alternative methods of controlling weeds in the absence of synthetic herbicides.

Recommendations
The recommendations are particularly relevant to Government bodies with both the capacity and also the interest of the new and emerging rural industries at their heart.

(PRJ-007079)
Targeted control of seed production in the weed wild radish

Researcher/contact
A/Prof Ed Newbigin
University of Melbourne

What the report is about
This report describes research on a novel approach to managing wild radish populations with treatments that reduce seed production.

Who is the report targeted at?
The information in this report is relevant to rural research organisations, particularly those delivering benefits to Australian grain growers. Given the impact that wild radish has on crop production world-wide, commercial manufacturers of herbicides would also be interested in the results of this project.

Where are the relevant industries located in Australia?
Australia is a major producer and exporter of winter cereals such as wheat and barley and of oilseeds such as canola. Total winter crop production in 2010-11 was about 42 million tonnes and canola production was about 2 million tonnes. Agricultural exports contribute significantly to Australia’s GDP. Wild radish is widespread across Australia and is one of the most serious and competitive broad-leaved weeds on Australian farms, having a major economic impact on crop production in southern Australia (NSW, Vic, SA and WA). Australian farmers located in the southern cropping zone are potential beneficiaries of this research.

Background
Wild radish (Raphanus raphanistrum) is one of the most problematic weeds of Australian agriculture, annually costing the grains industry $140 million in lost yield and protection measures. As herbicide resistance is an increasing problem, it is expected that the approaches currently used to control wild radish will become less effective over time. Because the herbicides used to manage wild radish do so by controlling vegetative stages of plant growth, this project explores the possibility of managing wild radish populations by reducing their ability to produce seed and thus stop the accumulation of weed seed in the soil. By depleting the seed bank, this project targets the Achilles’ heel of annual weeds like wild radish.
Aims/objectives
The main objectives of this research were to:

1. test a range of simple chemicals for their ability to interfere with wild radish seed production by causing the flower to reject all pollen; and

2. to obtain field-based demographic data for wild radish under a range of cropping conditions to quantify the effects that reducing seed set will have on the population.

Methods used
A range of experiments on the effect of chemicals applied to the flower on pollen grain germination and pollen tube growth was conducted. The outcome of these applications was monitored by microscopy. Field-based demographic data on wild radish populations was obtained by monitoring flowering, seed production and growth rates of plants growing in wheat paddocks in Western Australia, South Australia and New South Wales.

Results/key findings
Wild radish has self-incompatibility (SI) system that acts to prevent a flower being fertilised by its own or genetically similar pollen (while still accepting other compatible pollen types) and is well understood at a molecular level. Increasing the levels of reactive oxygen species (ROS) produced by the stigma can potentially activate the SI system to reject all pollen, as ROS levels regulate a key sensing protein that controls self-pollen rejection. A method was developed that allowed the effect of selected chemicals and enzymes on stigmatic ROS production to be measured. Two chemicals, sodium pyruvate (SoP) and ascorbic acid (AA), were identified that were well tolerated by the plant and increased ROS levels in the stigma three-fold. A pollination assay was then developed to determine whether these chemicals would also cause stigmas to reject compatible (i.e., non-self) pollen as expected. Stigmas treated with SoP or AA rejected compatible pollen in a manner that suggested the self-incompatibility response of wild radish had been activated. As the results are based on small-scale assays, further glasshouse and field-based testing is required in order to establish its effectiveness of this approach to wild radish management.

Values for survival rates, reproductive output and seedbank density for wild radish plants growing in wheat fields were obtained for sites in WA, SA and NSW. For seed production, the most important variable was whether the wild radish plant was above or below wheat height, with plants that grew taller than wheat producing 10 times as much fruit as plants that were below the wheat.

Implications for relevant stakeholders
With herbicide resistance an increasing problem in wild radish, there is a need to develop alternative approaches to weed management that improve the sustainability of crop production systems and increase the useful life span of currently used herbicides. Reducing weed fecundity as an option for wild radish management is worth exploring further and future work should focus on demonstrating that the effect seen here in small scale tests is transferrable to larger scale glasshouse trials and subsequently field trials. Based on the demographic studies, the plants that produced the most seed were those that grew taller than the surrounding crop, suggesting these plants should be the focus any measures aimed at reducing the amount of seed entering the seedbank.

Recommendations
The lead scientists involved in this project envisages working with key rural research organisations and agrochemical companies to further determine the potential of this weed management tool for control of wild radish seed production.

Communications
Papers based on this work are being prepared for publication in Sexual Plant Reproduction and Austral Ecology. (PRJ-007103)

"Stigmas treated with SoP or AA rejected compatible pollen in a manner that suggested the self-incompatibility response of wild radish had been activated."

""
Containment of invasive plants: a basis for decision making and best practice

Researcher/contact
Dr Tony Grice
CSIRO

What the report is about
This work sought research-based principles for containment as a major strategic option for addressing problems of invasive plant species. The principles have been developed using a combination of computer models and case studies.

Who is the report targeted at?
This report targets weed management strategists including those operating in the realms of either policy development or on-ground action.

Where are the relevant industries located in Australia?
This project provides a scientific basis for assessing containment as a strategic option and determining whether it is feasible in particular cases and how best to achieve it. The results are relevant anywhere strategic decision making is required for the management of pest plants, both in Australia and overseas.

Background
The general strategic options available for addressing problematic plant species include prevention, eradication, containment and suppression. Containment has received little research attention. Much of the discussion about containment implies that it is a straightforward fall-back option when eradication is deemed to be not feasible. It is important to provide a rigorous scientific basis for assessing the feasibility of containment and how it can most efficiently be achieved.

Aims/objectives
1. Develop a decision tree for deciding between strategic management objectives (eradication, containment, asset protection) for invasive plant species
2. Develop and analyse five site- and species-specific case studies where containment is the strategic objective;
3. Derive general principles for assessing the feasibility of containment as a strategic objective and for efficiently achieving containment of invasive plant species;
4. Promote the application of the general principles to the containment of invasive plants who may benefit from the research.
Methods used
A decision-tree was developed to decide between major strategic options for countering plant invasions. The existing literature on containment was reviewed and a rigorous definition proposed. An existing model was adapted to analyse key relationships between biological processes, spread and countermeasures to contain that spread. Five case studies were developed with collaborating organisations. They were explored by tailoring the general model. Containment principles were developed from the results.

Results/key findings
A decision tree is available to weed managers incorporating decisions relating to containment. In the long-term, breaches of any containment unit as defined by this research is inevitable. Failure of the containment effort can then only be avoided through eradication of the target plant outside of the containment unit. Containment is not always an easier or more cost-effective option compared with eradication. The feasibility of containment of an infestation is a function of the ratio between the area of that infestation and the plant’s dispersal capacity. Specific models are available to support decision by the organisations with jurisdiction over the five case study species/situations.

Implications for relevant stakeholders
The “weeds management” industry has a basis for a more rigorous approach to containment.

Communications
Three papers submitted to the Australian Weeds Conference (October 2012):

1. Grice, Clarkson, Friedel, Murphy, Fletcher and Westcott. Containment: the state of play.
2. Clarkson, Grice and Dallery. Chasing the lion’s tail: a review of the management of Leonotis nepetifolia L. R.Br. on Rinyirru National Park.

Presentations on containment to the National Tropical Weeds Management Committee (Siam weed (4 May 2012)); Cape York Savanna and Wet Tropics regional QPW staff annual fire and pest workshops (Townsville & Cairns); the Far North Queensland Pest Advisory Forum on principles of containment in weed management strategies.

Workshop with staff of a major northern Australian mining company regarding control and containment options for gamba grass (Andropogon gayanus) (30 March 2011).

Workshop with QPW staff regarding management options, including containment of pest plants on Cape York Peninsula (18 May 2012).

Provided input on containment as a management option to a discussion paper on terminology that is being prepared for the Australian Weeds Committee.

Recommendations
The recommendations from this work target strategic weed managers eg WoNS co-ordinators, NRM bodies, state agencies and land managers who make decisions about weeds.

- A clear definition of containment should be applied. This project proposes: containment is deliberate action taken to prevent establishment and reproduction of a species beyond a predefined area.
- Containment should be considered in the context of a clear decision-making process relating to strategic directions. The decision-tree provided by this project provides such a context.

- Containment should be at a scale that closely reflects the target plant’s dispersal capacity.
- Containment programs should be fashioned to individual species and circumstances, reflecting landscape patterns.

There is a more informed basis for high level strategic decisions about the management of individual weeds such as WoNS and national eradication targets.
Weed management on Indigenous lands: Indigenous values, perceptions and capacity

Researcher/contact
Dr Tony Grice
CSIRO

What the report is about
This report examines Aboriginal people’s perspectives on weeds and considers how weed management might be made more effective.

Who is the report targeted at?
Aboriginal and non-Aboriginal agencies responsible for policy, funding and management of Aboriginal lands; Aboriginal communities, ranger groups and their partners.

Where are the relevant industries located in Australia?
Approximately 20% of Australia, including 50% of the Northern Territory, is Aboriginal-owned. Most Aboriginal-owned land is in remote regions in central and northern Australia.

Aboriginal-owned land is managed for multiple uses and values including conservation, tourism, commercial cattle production, traditional/cultural uses and mining.

Aboriginal people also have customary custodial responsibilities over other lands.

Background
Weeds invade Aboriginal-owned lands, as they do other lands, and affect economic, environmental and cultural values.

People’s perspectives on weeds influence their objectives and efforts in weed management. Aboriginal perspectives, objectives and efforts are not well understood.

Aims/objectives
1. To describe weed problems on Indigenous lands of five diverse regions;
2. To identify Indigenous perspectives on those weeds, including threatened values;
3. To compare and contrast them with non-Indigenous perspectives;
4. To review weed management activities undertaken in the target regions;
5. To identify ways in which the capacity of Indigenous owners to address weed issues of concern to them can be enhanced;
6. To develop more general conclusions, through synthesis of learnings from individual case studies, about Aboriginal perspectives on non-native species, directions for capacity building for weed control on Aboriginal lands in central and northern Australia, and implications for Aboriginal weed management elsewhere in Australia.
Some Aboriginal perspectives are like those of farmers: both experience weed impacts on natural resources that are important to their livelihoods. Other perspectives are similar to conservationists: both are concerned about impacts on biodiversity and ecosystem function.

Methods used
This project worked with five Aboriginal groups in diverse parts of northern and central Australia who manage Western Arunda lands (central Australia); eastern Yolgnu lands (Nhulunbuy region, north-east Arnhem Land, NT), Malak Malak lands (Daly River region, NT), Wik lands (Pormpuraaw, western Cape York Peninsula) and Nywaigi lands on Mungalla Station (coastal north Queensland). Interviews and/or workshops were held with community ranger groups and some elders/cultural knowledge holders. A common question framework was used to facilitate comparative analysis. Public data bases were used to identify potentially relevant non-native plant species.

Results/key findings
Aboriginal people are active in weed management. It helps people stay connected to country. There is a range of views within and between communities about ‘problem plants’. Some non-native species are a major concern and some others are seen as useful. Some native species are seen as plants that can ‘take over’ if unmanaged. Awareness of weeds and the problems they cause is greatest amongst Aboriginal people who are actively engaged with their land, through working as rangers or in customary harvesting.

Some Aboriginal perspectives are like those of farmers: both experience weed impacts on natural resources that are important to their livelihoods. Other perspectives are similar to conservationists: both are concerned about impacts on biodiversity and ecosystem function. Aboriginal people’s distinctive perspectives include: weeds making land harder to access, changing cultural landscapes, destroying habitat for valued food species, posing safety risks, and disturbing the integrity of cultural relationships to land for future generations.

Most of the weeds of greatest concern are recognised in legislation (e.g. Weeds of National Significance) but some are not. Buffel grass is a major species of concern in central Australia.

All groups have applied consistent effort and had considerable success in some aspects of weed control (e.g. Athel pine on Western Arunda lands; near-elimination of Parkinsonia on Wik lands; strong progress with Mimosa pigra on Malak Malak lands; vigilance for early detection of weed threats and control on eastern Yolgnu lands). Other problems are seen as intractable and effort is focused on small areas with key assets (e.g. buffel grass control at a bush food harvest site and an endangered species habitat on Western Arunda lands).

Ranger groups are active in building awareness of weed threats. Although weed control is very hard work, some Aboriginal people are passionate about it because they are seeing the difference it makes or have seen the huge problems that weeds are causing in other places. A diversity of management structures exists amongst the case study groups. No single model would fit the various local circumstances. Some groups struggle constantly for resources. For others, the Working on Country Program has brought a big increase in capacity. Lack of continuity of resources is already a problem or is a threat to all groups. Flexibility is also needed (e.g. for increased effort after big rains).

Structures and funding to coordinate weed management between Aboriginal-owned and other lands are important and under-developed.

Implications for relevant stakeholders
Weed management on Aboriginal lands benefits the public good, not only Aboriginal people.

Remote settlements and roadsides are sources for infestation of Aboriginal lands but are often outside the responsibility of Aboriginal land management groups.

Weed management may provide opportunities for Aboriginal business development (e.g. Kakadu Native Plants, an Aboriginal enterprise, manages weeds for mining industry clients).

Recommendations
Secure continued resourcing for ranger groups is important for effective weed management.

More coordinated effort is needed for effective weed management across tenure boundaries.

Communications
Workshops involving representatives of collaborating Aboriginal communities.

Case study reports provided to collaborating Aboriginal communities.

Professionally produced video available through the CSIRO web site.

Conference presentations and journal papers from case studies and overall findings.

(PRJ-007107)
The use of weed sensors for variable rate herbicide application: Wimmera

Where are the relevant industries located in Australia?
Weeds, both annual and perennial are prevalent with broadacre cropping systems in north-west Victoria. Annual farm expenditure on herbicides is around $60/ha within the Wimmera-Mallee region. There are over 2 million hectares of land dedicated to broadacre cropping. Any reduction in the cost of controlling weeds in this region would benefit grain growers significantly, and could be more substantial in the longer term if weed sensing technology was successful and adopted. Weeds are present throughout Australia, so the findings of this report can be applicable to all Australian broadacre cropping enterprises.

Background
The recent adoption of No-Till farming (minimal or zero soil disturbance) over the past decade has seen a greater reliance on herbicide used for weed control. Under the No-till farming system, herbicides represent one of, if not the greatest cost Wimmera and Mallee farmers incur. This practice change has also led to adoption of new precision technology such as variable rate seeding equipment and fertiliser spreaders that farmer are now currently using to reduce over expenditure, whilst still maximising yields. Although crop and weed sensing technology has existed as a research tool in Australia since 1984, until recently this technology has had limited commercial use in southern Australia. WeedSeeker® is one of the commercial weed sensors currently available. The sensor is able to identify a green plant, through the different reflectance it emits, which will then activate the spray nozzle to apply the herbicide automatically. Given sporadic weed germination, weeds varying in size and distribution; this technology could potentially reduce the quantity and cost of applied herbicides significantly giving an economic and environmental benefit. If proven to be viable, this may led to reduce herbicide costs, increase efficiencies and greater farm viability.

Aims/objectives
The objectives of this study are to:
1. Determine the situations and weed populations where the use of weed sensing equipment can be economically justified.
2. Develop key strategies and practices that maximise the potential gains from weed sensing technology.
3. Increase the awareness of the benefits of weed sensing technology such as WeedSeeker® and to increase adoption within the Wimmera Mallee region.
4. Establish if WeedSeeker® technology has a whole farm benefit, if this equipment was to be adopted.
Methods used
The project was designed to investigate four main aspects; commercial application and benefit, fundamental thresholds for problematic weeds, quantify the potential savings on a regional level and determine the economic benefit of retro-fitting the sensor technology onto an existing boom.

To determine the application and benefit of a commercial boom, fitted with WeedSeeker® was used in four large scale replicated paddock trials. Paddocks were chosen to represent situations where farmers would normally have to spray, but the weed population was sporadic. Through alternating spray passes using WeedSeeker® technology compared to blanket application, herbicide efficacy and any reductions in water usage were determined.

Two small plot replicated trials were established with various crop types at different plant densities. Using a custom built 1.6m wide spray unit, fitted with WeedSeeker®, the amount of water used for different plant densities of common broad-leaf and grass weeds was calculated. The information was then used to identify the particular thresholds where the technology is advantageous.

A random survey within the region was undertaken to determine the incidence of the determined thresholds. This entailed the use of the custom built 1.6m boom and spraying a single strip for the length of a paddock. The amount of water used was captured and measured.

The economic study used the results obtained from the above components to determine the overall farm benefit and profitability of this technology if it was to be adopted on an average Wimmera and Mallee farm. The study used actual costs associated with purchasing the equipment and included are loan repayments and interests.

Results/key findings
This study has confirmed that significant reductions in water and herbicide use can be achieved if farmers adopt weed sensing technology. The commercial paddock trials demonstrated that weed efficacy and control are equally as effective when compared to current practice. The reduction in water use varied between 20-90% depending on the size and densities of weeds in the paddock with an average reduction of 52%. This has the potential to double the area sprayed per tank load, increasing spraying efficiency. Thresholds for grasses and broadleaf weeds were determined and highlighted that even dense populations of weeds could still generate significant savings, whilst broadleaf weeds require lower plant densities for it to be economic. These savings were found to be greater in the paddock survey, with approximately 60% less herbicide required as a pre-sowing knockdown.

The economic analysis found that savings can be achieved through the adoption of weed sensing technology by either utilising contractors with weed sensing fitted booms or by purchasing it outright. At present there is $4/ha difference in cost between a farmer blanket operation ($6/ha) and contract WeedSeeker® operation ($10/ha). As such growers considering using contractors with weed sensing fitted booms will need to achieve at least $4/ha of savings in herbicide costs through reduced application. These saving can easily be achieved when the cost of the herbicide is high and the density of weeds is low.

The economic analysis of purchasing WeedSeeker found that the larger the farm the shorter the amount of time it takes to cover the cost associated with purchasing WeedSeeker®. It is also apparent that it would take a Wimmera farmer more time to cover the cost of WeedSeeker® compared to the Mallee farmer due to the reduced saving from using WeedSeeker® possibly due to smaller land holdings and different soil types. However, the analysis revealed that WeedSeeker® is a viable option for the majority of farmers in the Wimmera and Mallee. If the farm was too small to warrant the investment the shortfall could be overcome by contracting to other farmers supplementing income.

Implications for relevant stakeholders
Weed sensors have substantial advantages to reduce chemical expenditure and improve labour efficiency. These tools would allow growers to spray a paddock without having to apply economical thresholds. In the longer term, this will result in reduced weed seed set from escapes and provide growers with more crop options. The knowledge obtained from this study has increased grower awareness of weed sensing equipment and potential advantages that may occur.

Recommendations
Further research is required to investigate the various combinations of the effects of stubble and herbicide rate and combinations for blanket applications.

Communications
PRESENTATIONS
Use of Weed sensing technology, BCG Trials Review Day, Birchip February 2012 (220 farmers attended).

Using WeedSeeker for controlling weeds, BCG Main Field Day, Corack, September 2011 (510 farmer, advisors and researchers attended).

PUBLICATIONS

“WeedSeeker technology”, BCG 2011 season research results, February 2012.


OTHER EVENTS AND COMMUNICATION
“From Rain to Grain”, BCG Grains Research Expo, 7 July 2011.


(PRJ-007124)
Managing weeds on native title lands

**Researcher/contact**
Dr Jessica K Weir
AIATSIS

**What the report is about**
This research report considers the implications of native title for weeds management. In particular, the report highlights two aspects: the legal question of who is responsible for weeds on native title lands; and the practice of how weeds management is undertaken on native title lands, which is examined through a case study on the Kimberley.

**Who is the report targeted at?**
This report is relevant for native title holders and institutions, weeds managers and policy makers, and people engaged more broadly in natural resource management activities on native title lands.

**Where are the relevant industries located in Australia?**
The report is relevant to native title lands located across Australia.

**Background**
The retrospective recognition of native title has required a re-interpretation and revision of the laws and governance of the Australian federation, including those of relevance to weeds management.

**Aims/objectives**
Broadly, the objectives have been to consider:

- the implications of the changing nature of land ownership for weeds management in Australia;
- the weeds management priorities of native title holders; and,
- the opportunities and limitations of current weeds institutions, policies and programs with respect to native title holders.
There is a lack of clarity in most jurisdictions around the legal responsibilities of native title holders for weeds management. However, in all states except Queensland, it is reasonably likely that exclusive possession native title holders would be caught by the legal definition of ‘owner’ or ‘occupier’ for the purpose of statutory weeds management obligations.

Methods used
A multidisciplinary, multi-method approach was taken to this complex and broad topic in order to produce research that is both national in reach and locally grounded with a case study. This has been achieved through a combination of three research activities: a desktop literature review; a facilitated workshop and workshop report; and a research report.

Results/key findings
There is a lack of clarity in most jurisdictions around the legal responsibilities of native title holders for weeds management. However, in all states except Queensland, it is reasonably likely that exclusive possession native title holders would be caught by the legal definition of ‘owner’ or ‘occupier’ for the purpose of statutory weeds management obligations.

In jurisdictions where the official declaration of priority weeds is weighted towards the narrow economic cost of weeds on primary production, official priorities are unlikely to align with native title holders.

Weeds management is not just a scientific or technical undertaking. There are important procedural considerations that need to take account of the cultural context of the areas where weeds are being managed.

Implications for relevant stakeholders
To the extent that native title holders have legal obligations to control weeds, there is a mismatch between the legal obligations and the resources available, resulting in both a burden for native title holders and a gap in the collective provision of weeds management.

Recommendations
The authors recommend that policy makers and legislators:

• undertake legislative amendment to make provision for flexibility regarding statutory weeds management obligations;
• recognise general principles for weeds management on native title lands in policy documents;
• undertake case-by-case negotiated arrangements, recorded in native title agreements and/or native title determinations;
• implement policy change to address resource issues for native title corporations.

Communications


(PRJ-007131)
Invasion and impact of high biomass grasses in Queensland

Researcher/contact
Dr Daniel Metcalfe
CSIRO

What the report is about
This report establishes the distribution of introduced high biomass grass (HBG) species across northern Queensland, and considers the potential impact they may have both directly and indirectly.

Who is the report targeted at?
It is relevant to land managers, national park rangers, local councils and agencies responsible for policy and funding for natural resource and pest plant management. Gamba grass was declared a Weed of National Significance (WoNS) in April 2012.

Where are the relevant industries located in Australia?
High biomass grasses are spread throughout northern Australia, particularly in savannah woodland and rangeland communities, where they have the potential to significantly alter natural fire regimes as well as impacting on biodiversity and ecosystem processes.

The project considered the distribution of thirteen introduced species across over 350,000 km² of Cape York, Northern Gulf and the Wet Tropics NRM regions, including species scheduled as weeds in Queensland, species not scheduled in Queensland but scheduled in other states and territories, species not scheduled in Australia at all, and species used by the pastoral industry for beneficial reasons, but which may share similar characteristics of invasive species if not appropriately managed.

The savannah woodlands and rangelands of northern Queensland are predominantly used either for extensive agriculture, namely beef production, or are protected areas under National Park or other form of conservation management or indigenous management arrangements.

Understanding the distribution, spread, impact and potential of high biomass grasses across northern Queensland will support the policy-making, management and in some cases control of these introduced species.

Background
Exotic grasses have been introduced across much of Australia's savannah grazing land to replace native pastures and support extensive grazing of cattle. Many of these species have naturalised to the extent that they now pose considerable threat to natural systems, ecosystem processes and biodiversity. Several of them also have value as pasture species, so cause conflict between environmental managers and pastoralists. Amongst these conflict species are a number of high biomass grasses (HBGs) which have the potential to alter community structure, fuel loads and therefore fire characteristics.

Our current knowledge of HBGs is largely informed by work on mission grass (Pennisetum polystachion) and gamba grass (Andropogon gayanus) in the eucalypt savannas of the Northern Territory; consequently we have a limited understanding of both the impacts of HBGs on biodiversity in the climatically different savannas of northern Queensland, on their distribution and on the invasion processes that facilitate their establishment.

Additionally, most HBGs are at a relatively early stage of invasion based on their potential distribution, on their densities in invaded ecosystems, and on the length of time they have been present in invaded communities.
This offers a timely opportunity for targeted management to minimise weed impact on cultural values, agricultural productivity and biodiversity. However, with limited knowledge of the characteristics of individual species or the responses of the ecosystems being invaded, this opportunity is at risk of being squandered.

**Aims/objectives**

This project had four key objectives:

1. A review of introductions of grasses into Queensland, which should inform policy makers and weed risk assessors of the pathways by which particular species became introduced.

2. A current distribution map for thirteen high biomass grass species across the region, generated with councils, state agencies and landholder input, to provide a baseline from which future spread can be monitored, potential containment lines identified, and management actions coordinated across jurisdictions.

3. An understanding of the patterns of spread of two species of concern (olive hymenachne and grader grass) in Lakefield and Undara National Parks respectively, in collaboration with Queensland Parks & Wildlife.

4. Vertebrate surveys in areas with different histories and intensities of invasion to inform understanding of the impacts of high biomass grasses on biodiversity and ecosystem processes.

**Methods used**

A review of grass introductions in Queensland was completed following exhaustive literature survey and interrogation of the Australian Virtual Herbarium; the mapping data was generated by interviews with Shire pest officers, Queensland Parks & Wildlife staff, DEEDI beef extension officers and the like, and the vertebrate sampling was done using a standard published methodology under existing permits and ethics approvals to CSIRO Ecosystem Sciences staff.

**Results/key findings**

Overall, the study of invasive grass species suggests that greater emphasis is required on understanding potential impact rather than invasiveness per se when assessing the threat that may be posed by a particular species, and the importance of considering the historical context of invasions when predicting future threats.

Current distributions have been determined, and these data are readily available in map form from the FNQROC website.

Olive hymenachne had invaded Lakefield National Park just before the project began, which highlighted the importance of native species (birds) as vectors and the need for regular surveillance of sensitive areas.

Sites were selected for vertebrate survey on the basis of high biomass grass species being present at or near the site during previous surveys, at three separate areas in the conservation estate (Brooklyn Fauna Reserve, Blackbraes and Undara National Parks). Twenty-one sites were surveyed in Nov-Dec 2011, but rain prevented access to the final 10 sites, which will be surveyed in November 2012.

A full analysis of changes in vertebrate species composition and density over time corresponding to invasion of high biomass grasses is pending.

A completely unexpected finding in the vertebrate surveys in Blackbraes National Park was the identification of the chubby gungan Uperoleia rugosa, a species of frog previously unknown from the area – this represents a known-range extension of approximately 700km!

The review may help guide policy makers in the ways they implement risk assessments; the mapping products should enable coordinated management across large areas of northern Queensland, and the pending biodiversity data should support land managers understand the complexity of the impacts of invasive grasses, and the also the potential indirect impacts of appropriate control methods, particularly use of fire.

**Implications for relevant stakeholders**

Species used by the pastoral industry for beneficial reasons, but which may share similar characteristics of invasive species if not appropriately managed (e.g. buffel and para grass) need to be closely monitored to ensure that they are not allowed to escape into the environment from managed situations, as their potential impacts are widespread and serious.

Monitoring future developments in extent and impact of weedy grasses, and where threat assessments are most warranted and best focussed, will be supported by publication of the review of grass introductions (Van Klinken, Panetta & Simon) which provides an up to date understanding of the range of species introduced in Queensland, their mode of entry, means of spread and current status.

Current distribution data for target species is now publically available from a single website.

**Recommendations**

The findings are directed at policy makers, in terms of understanding invasiveness of introduced species, at land managers, in terms of understanding the indirect impacts of high biomass grass invasion on vertebrates, and at weed control agencies and managers in providing a current map of distribution across all management jurisdictions in northern Queensland, enabling a coordinated approach.

(PRJ-007137)
Desert Uplands: control of Parthenium and Mother-of-Millions

There is a strong case for a strategic focus on local eradication and regional control to avoid weeds moving to the headwaters of new catchments.

Where are the relevant industries located in Australia?
Parthenium weed is currently infesting core areas of central Queensland, particularly in the Fitzroy and Burdekin catchments, with other areas of infestation in regional Queensland, New South Wales and the Northern Territory. Mother-of-millions weed is a widely distributed species across eastern parts of Australia, particularly in Queensland and New South Wales.

Background
Parthenium is a Weed of National Significance (WoNS), introduced to central Queensland in the 1960s in pasture seed. It has potential to spread across all medium rainfall rangelands and summer cropping areas in the country. It causes production losses in pastoral and cropping industries, impacts on biodiversity, and causes allergenic reactions in humans.

Mother-of-Millions is a Class 2 weed, with widespread distribution because of historical use as a garden ornamental plant. The species is poisonous to livestock and humans, causes production losses in pastoral industries, and impacts on biodiversity, particularly in areas of remnant woodlands and along watercourses. It has potential to be widespread across eastern Australia because of its tolerance to different climates and ability to survive droughts.

Aims/objectives
The main objective of this research is to understand the effectiveness of different weed control options for isolated and scattered outbreaks, particularly focusing on the incentives facing landholders to control. In particular, the aims were to:
1. evaluate the most suitable methods of control in the rangelands area of interest,
2. identify the cost-effectiveness of different control options,
3. capture expert knowledge about the characteristics of weed infestation and management in the region of interest (the Desert Uplands bioregion), and
4. model how variations in the costs and benefits of control are likely to influence adoption rates.

Researcher/contact
Dr Professor John Rolfe
Central Queensland University

What the report is about
This report is about the effectiveness and economics of controlling scattered outbreaks of parthenium and Mother-of-Millions in rangelands ecosystems. The focus of the project was to investigate the effectiveness of control options to avoid the weeds spreading from the eastern side of the Great Dividing Range in central Queensland to Murray-Darling and Lake Eyre basins.

Who is the report targeted at?
The knowledge created with this project will be valuable to policy makers involved in strategic weeds management in rangelands areas. The information in this report will also be of interest to landholders involved with control of parthenium and Mother-of-Millions.
Methods used
The project involved a number of trial control sites on grazing properties across the regional area to test the effectiveness of different treatment mechanisms for the two weeds of interest and to engage landholders in the research process. Two types of control were tested for each weed and compared against untreated control sites, involving eleven different grazing properties. Expert opinion was captured from landholders and other experts with interviews, field visits and a workshop on a grazing property. Information from a desktop review, the field trials and the capture of expert opinion was then used to model the costs and benefits of control across a range of different scenarios. Implications about factors affecting adoption were then drawn.

Results/key findings
Key findings in this project were:

• Some treatments were identified as highly effective, particularly the use of broad-leaf herbicides for parthenium, and a combination of fire and broad-leaf herbicide followup for Mother-of-Millions. The use of low-cost broadleaf herbicides is preferable because pasture competition is maintained and enterprise viability is maximised.

• Brush Off®, a broadleaf herbicide based on metsulfuron-methyl as the active ingredient, was found to be effective and low cost for control of parthenium and mother of millions.

• The net benefits of control at both enterprise and public levels are high because of the very small levels of current infestation and the potential for widespread infestation into the western and southern basins. However, individual landholder preferences for control may vary, in part because of heterogeneity of enterprises and landholders, and because of wide variations in search and control costs.

There is a strong case for a strategic focus on local eradication and regional control to avoid weeds moving to the headwaters of new catchments.

• Involving landholders in field trials and research programs helps to generate interest and adoption. To be fully effective, field trials should be held over multiple seasons.

Implications for relevant stakeholders
There are net benefits in the control of scattered outbreaks of both parthenium and Mother-of-Millions in the Desert Uplands, although the public benefits are higher than the enterprise-level benefits. At a strategic level, there are very high benefits in pursuing local eradication strategies. However, variations in net benefits at the enterprise level and path-dependence of net benefits in control (coordination issues) mean that widespread control efforts by landholders may not eventuate without mechanisms to encourage coordination.

Recommendations
Control of weeds in strategic areas, and mechanisms to engage landholders in surveillance and control efforts should be prioritised, taking account of substantial variation in the benefits and costs involved at the individual landholder level. The use of effective control strategies with low-cost broadleaf herbicides should be communicated to landholders for key weeds of interest. Herbicides based on metsulfuron-methyl as the active ingredient should be registered on-label for treatment of Mother-of-Millions.

Communications
PRESENTATIONS

PLANNED PEER REVIEWED PUBLICATIONS
Economics of controlling scattered outbreaks of weeds in rangelands ecosystems Australian Journal of Agricultural and Resource Economics.
(PRJ-007143)
Precision sensing technology for infield identification of summer weeds

Researcher/contact
Dr Cheryl McCarthy
University of Southern Queensland

What the report is about
A proof-of-concept standardised precision weed sensing system has been developed to target difficult to control weeds in fallow fields for the cotton and grains industries. The technology uses machine vision to identify infield weeds for the purpose of informing weed management strategies and has potential use to map and selectively spray infield weed infestations.

Who is the report targeted at?
This report will be of interest to industry stakeholders including growers, research and development corporations, weed researchers, chemical companies, technology suppliers and field agronomists. The research will inform the further development and evaluation of a precision weed sensing system to assist management of glyphosate-resistant weeds.

Where are the relevant industries located in Australia?
Weed control methods are required that optimise yield and reduce herbicide usage whilst reinforcing the minimum tilling farming concepts being adopted by Australian industries. As such, precision weed identification is applicable to a number of industries. The focus of this project is weeds of significance to the cotton and grains industries in Queensland and northern NSW. The project team has also been developing a weed identification system for the Australian sugarcane industry which has benefited from the technology.

Background
The adoption of minimum- and no-till farming has led to new weed problems that were previously inherently controlled by tilling practices. Problem weeds have also been found to develop a resistance to glyphosate, resulting in ineffectual control of the weed by conventional herbicide tank mixes. Technology is required to identify weeds such as fleabane in minimum- and no-till farming and to identify emerging glyphosate-resistant weed patches in the field so that appropriate control strategies can be determined.
The research demonstrates that discrimination of weed species in real-world on-farm conditions is achievable using combined colour and depth image analysis.

Aims/objectives
The aim of this project is to provide a ground-based machine vision technology that will enable automatic detection of potential glyphosate-resistant weed patches in fallow fields and in crops. The specific objectives of this research are to:
1. develop and prototype machine vision and sensing technology which will provide an aid to combating glyphosate resistance,
2. identify how technology can assist the delay of emerging and ongoing resistance by using herbicides more strategically and targeting their use.

Methods used
A new image analysis technique was proposed to achieve grass from broadleaf discrimination and for discriminating different broadleaf species. Active and passive methods of depth data generation were investigated so that weed segmentation based on height could be used as a pre-process to more computationally-intense colour-based algorithms.

Results/key findings
Automated analysis of colour images enabled extraction of individual grass leaves (liverseed, wild oats, feathertop Rhodes grass and wild sorghum) and discrimination of grasses from broadleaf weeds (sowthistle and fleabane). A greater resolution was required for broadleaf species feature extraction than for grass species identification. An active depth sensor was found to reduce image complexity by at least 80% for images containing weeds at a distinct height, e.g. standing grass amongst low-lying broadleaves and grasses.

The research demonstrates that discrimination of weed species in real-world on-farm conditions is achievable using combined colour and depth image analysis. Further work is required to further develop the weed classifier for the cotton and grains industries. Potential strategies for automatic selective spraying of identified weeds are spraying at the time of identification, as well as returning later to apply a ‘double knock’ and potentially returning again for a ‘triple knock’ by applying a pre-emergent suitable for that particular weed. The technology might be used to map weed locations over time to evaluate weed control strategies.

Implications for relevant stakeholders
A technology that automatically detects infielde weeds offers potential environmental and cost benefits to the cotton and grains industries whilst combating herbicide resistance. Farmers in the cotton and grains industries who are implementing Integrated Weed Management strategies will benefit from this research. The research will benefit chemical companies by reducing herbicide resistance and will benefit the environment by reducing the amount of herbicide used.

Recommendations
Combined colour and depth sensing has been demonstrated to achieve infield sensing of different weed species in real-world Australian on-farm conditions and further development and evaluation of the proof-of-concept system should continue through to commercialisation.

Communications

PRESENTATIONS
Preliminary evaluation of shape and colour image sensing for automated weed identification in sugarcane, 34th Annual Conference of the Australian Society of Sugar Cane Technologists, Cairns, May 2012 (reviewed conference paper).

Depth and colour image sensing for discrimination of sugarcane and wild sorghum: first results, International Society of Sugar Cane Technologists Workshop, Townsville, September 2012.

The project team’s work in sugarcane led to the opportunity to present at these conferences.

PLANNED PEER REVIEWED PUBLICATIONS
Line detection for grass from broadleaf discrimination, Computers and Electronics in Agriculture.

Active depth sensing for infield weed identification, Computers and Electronics in Agriculture.

Extraction of smooth leaves from weed rosettes on textured backgrounds, Biosystems Engineering.

(PRJ-007164)
Systematic review of Australian weed-related social surveys

Researchers
Dr Lyndal-Joy Thompson
ABARES

What the report is about
The project reviewed and analysed published literature reporting on previous social survey-based research fitting within the scope (120 publications were found); actual survey instruments used (56 were obtained); and advice from weed experts via an expert forum and subsequent Delphi process.

Who is the report targeted at?
This information is particularly valuable for researchers, research agencies and funders, and government policymakers and program managers.

Where are the relevant industries located in Australia?
Nationally.

Background
Weeds are a very serious problem in Australia, affecting virtually all environments, including farmland, forests, native vegetation, urban parks and gardens, and aquatic environments. They result in social, economic and environmental impacts that affect all Australians. One component of weed-related research is the use of social surveys to investigate matters like stakeholders’ perceptions of weeds; what they do to address weed issues; what encourages or hinders them in taking action; and from where they obtain weeds-related information. While a considerable body of research of this kind already exists, no previous systematic review appears to have been undertaken. Accordingly RIRDC commissioned ABARES to undertake this review and prepare a synthesis of previous Australian social survey research, and the questions used in relevant surveys.
Aims/objectives

- To systematically review weed-related social survey research in Australia
- To examine what questions had been asked over time, what gaps existed in relation to weed management and perceptions, how appropriate were the methodologies used, and what use had been made of research findings or data collected from past surveys
- To identify questions that could be built into existing surveys or a new ongoing survey to measure weed management behaviour and perceptions over time
- To explore alternative methods of collecting weed-related data
- To review past and current social, economic and institutional research and other information related to weeds and weed management in Australia to help identify a future research agenda that could help address national priorities for weed management

Methods used

To review and analyse weed surveys.

Results/key findings

Review and analysis indicated that much previous research was directed at farmers and other rural landholders, and there was a relative neglect of other stakeholders, including urban dwellers, culturally and linguistically diverse groups, and Indigenous people. Little research dealt with weeds affecting forestry or aquatic habitats. In particular, there was little focus on stakeholders involved along key risk pathways for weeds to spread once in Australia. The main research focus was on current weed management issues with relatively little emphasis on past or likely future issues. Research output appeared to be increasing over time but there was little evidence of trends in research topics or survey questions asked, other than those related to policy initiatives and funding programs current at the time. Few surveys were repeated. Little monitoring and evaluation appeared to be done either of outcomes of past research or previous weed-related programs or initiatives, making it difficult to assess how previous research was used or whether past expenditure had been effective. Alternative methods of collecting weeds-related social data included using ‘omnibus’ surveys; applying anthropological and ethnographic methods, particularly for weed issues in Indigenous communities; and making more use of electronic survey methods.

Implications for relevant stakeholders

A coordinated approach to weed surveys should be developed with better monitoring and collating of past and future surveys.

Recommendations

Suggestions for action were to:

- consider making particular under-represented groups, including culturally and linguistically diverse groups and Indigenous people, a possible focus for future surveys
- use pathway risk analysis in designing future surveys
- monitor and evaluate the use of social survey-based research
- frame weed-related issues as biosecurity issues
- prepare a comprehensive compendium of relevant social research.

Communications

Just how bad are coastal weeds: assessing the geo-eco-psycho-socio-economic impacts

Researcher/contact
Prof Roger Cousens
University of Melbourne

What the report is about
Australia’s coastal regions are being threatened by many invasive plants. Until now, there has been no data as to cost at any level of organisation, and there has not been an attempt to collate information on their environmental impacts. Thus, there is no basis on which to make management decisions which results, almost inevitably, in no action at all. This project collates existing information on the impacts of these invaders, collects new data on impacts on animals and people, and identifies the gaps in our knowledge and reporting systems.

Who is the report targeted at?
Policy-makers, coastal land managers, scientists.

Where are the relevant industries located in Australia?
This project is of national relevance: it applies to Federal bodies funding natural resource management and all States and Territories with coastlines. Within these regions, it applies to multiple tiers of government, agencies that are responsible for managing land such as state-wide and local community groups. Special attention was paid to the southern half of Australia. The main industries affected are tourism and the protection and management of Australia’s biodiversity.

Background
Australia has a narrow terrestrial coastal fringe of 60,000 km. This fragile habitat is undergoing a ‘coastal squeeze’: On the seaward side, sea levels are rising, reducing the width of beach available, and on the landward edge, there is severe threat from urbanisation, disturbance from tourism and invasive species – both plant and animal – particularly in the south and east. Intact habitat, with its unique flora and fauna, is now fragmented and increasingly rare. Yet, little action is taken to prevent the more than 200 weeds that are increasingly dominating them.

Aims/objectives
The aims were to document existing knowledge of the impacts of coastal weeds and to gain additional information through survey and observation.
Methods used
Scientific information on the impacts of coastal weeds/invasive plants was reviewed. All local government and state authorities were surveyed to determine expenditure on coastal weed management and on the main species that are actively managed. Coast Action/Coastcare coordinators were also contacted to assemble data on in-kind contributions from community groups. About fifty ‘citizen scientists’ made monthly records of animals interacting with invasive plants. BirdLife Australia volunteers and researchers in southern Australia made observations and measurements on the interaction between Hooded Plovers and weeds. Around 200 residents, visitors and coastal managers in the Bass Coast Shire completed a survey; follow-up interviews were conducted on a smaller sample, to understand perceptions of weeds in coastal landscapes. Aerial photographs were analysed between 1940 and today to map shoreline stability since the incursion by major weeds. Field mapping and laser surveying was undertaken at sites in Victoria to ground-truth the aerial mapping, and quantify how foredune morphology changes in response to weed infestation.

Results/key findings
The key results were:

• There is remarkably little scientific information on the impacts of coastal weeds in Australia. Most research has been on one or two species and most observations are not based on rigorous scientific study (Bitou Bush/Boneseed is the notable exception). Most weed control activities are not assessed for ecological impact, just (in some cases) herbicide efficacy.

• It is almost impossible to obtain data on weed management costs in most states. Coastal weed management costs at least $10 million, but this is a considerable underestimate particularly with respect to the State government sector.

• Local governments listed the top five species being actively controlled as African Boxthorn, Sea Spurge, Bitou Bush/Boneseed, Geraldton Carnation Weed and Bridal Creeper.

• With the exception of scenes dominated by Marram grass, visitors tended to have slightly lower preferences for weed-infested sand dune systems.

• All foredunes in Victoria are now composed of a mix of exotic and native species with the majority of sites showing the exotics to be replacing native species. Marram Grass, Sea Spurge and Sea Wheat Grass are the dominant invasive species displacing natives. Marram grass appears to cause dunes to become higher and narrower while sea wheat grass produces lower foredunes more seaward than those dominated by native species.

• Marram grass significantly impacts the availability and suitability of nesting habitat for beach-nesting birds such as Hooded Plovers.

Implications for relevant stakeholders
In probably the widest-ranging inter-disciplinary study of weeds ever undertaken, it has been illustrated just how little is known about coastal weeds and their impacts. They invade with impunity, with the exception of strong (though patchy) community action against a few species and a concerted effort against bitou bush. Without impact data, control decisions will tend not to be made in the face of alternative demands for resources. Without post-control monitoring data, it will not be known whether the expenditure has been worthwhile.

Much of the burden of management is shouldered by community volunteer groups.

Rapid change is currently occurring in dune shape and stability on the Victorian coast driven by weed invasion. This will significantly impact how shorelines respond to storms, leading to possible beach loss and consequences for town planners.

Recommendations
More scientifically rigorous studies of the main weedy/invasive species are needed; in southern Australia. Sea wheatgrass and marram grass would seem to be the most urgent of these. Where control is initiated, there should be more deliberate attempts to estimate the impacts of management action (and inaction). Critically, the response of dunes dominated by weeds to storm events needs to be quantified so as to enable managers to suitably respond to coastal erosion.

Communications
Communication was embedded in our project: we have communicated about coastal weeds by involving the public in collecting field data and local government officers who have provided data. An article on our project was published in The Voice, and an insert in The Age newspaper. We have also given a talk to the Weed Society of Victoria (19 April 2012). A full report will be circulated to all relevant State government bodies, local government and volunteers, along with research plans and a justification for future funding. We anticipate three other scientific papers in due course.

(PRJ-006866)

This will significantly impact how shorelines respond to storms, leading to possible beach loss and consequences for town planners.
Biological control of sea spurge phase 2

Researcher/contact
Dr John Scott
CSIRO

What the report is about
This report is about research carried out on the biological control of the coastal environmental weed, sea spurge (Euphorbia paralias). Two aspects were studied; a preliminary risk assessment of potential biological control agents from the native range and secondly, the ecology and impact of sea spurge in Australia to provide baseline data to assess the efficacy of biological control in the future.

Who is the report targeted at?
The information in this report will be of interest to coastal ecosystem managers in southern Australia who are involved in sea spurge control. The knowledge created with this project will contribute to the risk assessment of the candidate biological control agents, which will be completed should funding become available.

Initial results demonstrating that the candidate agents are likely highly specific indicate that further investment to complete a full host specificity program for these pathogens is warranted.

Where are the relevant industries located in Australia?
Sea spurge is currently widespread in coastal ecosystems across southern Australia. Sea spurge threatens a range of endangered species, aboriginal heritage sites and impedes public recreational use of coasts. The output of this research will be of interest to stakeholders involved in management of coastal ecosystems throughout southern Australia.

Background
Control of sea spurge infestations is difficult due to the presence of native vegetation, their close proximity to estuaries and marine environment, persistent seed banks, constant reinvasion from the ocean and limited access and resources in many remote areas of coastline. Conventional physical and chemical control techniques are inadequate to manage the weed. Sea spurge is an approved nominated target for biological control, which is the most viable option for long-term control. Surveys of the pests and diseases of sea spurge, conducted in 2008-2009 (during phase 1 of the project funded by CSIRO and the Tasmanian Department of Primary Industries and Water) in the native habitat on the Mediterranean and Atlantic coasts of France, found several potential biological control agents. Surveys of Australian populations of sea spurge, conducted during the same period, did not find any pest or diseases. Successful biological control programs against other European Euphorbia species in North America (e.g. leafy spurge) indicate the potential applicability of biological control to managing the impact of sea spurge in Australia.
Biological control of sea spurge remains a strong possibility for control of this weed because there are no other long term options available.

Aims/objectives
The main objective of this research was to advance our knowledge that will lead to biological control of sea spurge. In particular, the aims were to:
1. conduct initial host range and biology studies of potential biological control agents for sea spurge, and
2. gather baseline ecological data on sea spurge densities, distribution and impact on biodiversity for future studies to evaluate the effectiveness of biological control.

Methods used
In 2011-2012 baseline data was gathered on the plant’s ecology at three sites in WA and 3 sites in Victoria. Measurements of vegetative biodiversity associated with sea spurge were also made at five sites in WA and at three sites in Victoria to assess the possible impact on native vegetation.

During the same period, experiments were conducted at the CSIRO European Laboratory, France, to assess the potential of two fungal plant pathogens as biological control agents. The biology, cultivation and long-term storage of the leaf spot, Passalora euphorbiae (Mycosphaerellaceae) and the rust, Melampsora euphorbiae (Melampsoraceae) were investigated. A host test list was established that reflected the recent advances in understanding of Euphorbiaceae phylogeny, especially the number and structure of clades in the genus Euphorbia. Test plants were obtained, including native species from Australia and grown in the glasshouses in France.

Results/key findings
It was found that the considerable seed production of sea spurge is accompanied by low seedling survival, depending upon the seedling’s position on the sand dunes. The WA sites had predominately bare sand even when sea spurge was the dominant plant present whereas Victorian sites had a greater abundance of sea spurge.

So far, 19 and 17 plant species of the host test list have been tested or are undergoing tests for the rust and leaf spot fungus, respectively. Both pathogens have so far been highly host specific.

Implications for relevant stakeholders
The detailed knowledge of the ecology of the weed and host specificity of potential biological control agents are steps towards establishing a biological control program against sea spurge. Initial results demonstrating that the candidate agents are likely highly specific indicate that further investment to complete a full host specificity program for these pathogens is warranted. Once a full testing program is completed, approval to release these biological control agents in Australia will be sought from the relevant authorities.

Recommendations
Biological control of sea spurge remains a strong possibility for control of this weed because there are no other long term options available.

Communications

PRESENTATIONS
Paul Yeoh and John Scott gave presentations on sea spurge to coastal care groups.

A poster presentation will be given at the 18th Aust. Weeds Conference, 8-11 Oct., Melbourne.

PUBLICATIONS


PLANNED PEER REVIEWED PUBLICATIONS

A paper will be drafted on the weed ecology in Australia now that sampling has been completed and analysis started. Austral Ecology (or similar).

(PRJ-006967)
Cabomba ecology and dispersal in Australia

Researcher/contact
Dr Tobias Bickel
DEEDI

What the report is about
This report is about ecological research carried out on the submersed aquatic weed cabomba. The focus of the project was to investigate cabomba habitat requirements, dispersal abilities and colonisation potential.

Who is the report targeted at?
The information in this report will be of interest to water weed managers involved with cabomba control. The knowledge created with this project will also be valuable to scientists in the field of aquatic plant ecology.

Where are the relevant industries located in Australia?
Cabomba is currently present in Victoria, New South Wales, Queensland and the Northern Territory; it is still expanding its range. Cabomba significantly impacts aquatic ecosystems and interferes with irrigation, drinking water production and recreational activities throughout Australia. The output of this research will be of interest to stakeholders involved in management of water resources throughout Australia. Also, aquatic weeds such as cabomba are of great community concern in Australia due to the high visibility of the problem to the public.

Background
Cabomba is currently present in large parts of Australia and is still spreading. It poses a significant ecological and economic threat to Australian freshwaters as it reduces biodiversity through displacement of native aquatic plants and seriously interferes with human use of freshwater resources. Currently there is little knowledge about the habitat requirements and dispersal abilities of cabomba, severely hampering efforts to prevent further spread and to control this pest. Improved knowledge will increase efficacy of management strategies and reduce future control costs.
The detailed knowledge of habitat requirements will allow prediction of the future expansion of cabomba in Australia. Especially, it will permit identification of sites that are at increased risk of cabomba invasion, and therefore increased likelihood of timely detection and prevention of establishment.

**Aims/objectives**

The main objective of this research is to gain critical in-depth knowledge about the ecology of cabomba. In particular, the aims were to:

1. generate knowledge about the habitat requirements of cabomba  
2. get a detailed understanding of the competitive performance of cabomba compared to native macrophytes  
3. determine the regeneration ability of cabomba fragments,  
4. establish survival abilities of fragments and colonisation potential.

**Methods used**

A range of experiments was carried out in aquariums in the laboratory and outdoor mesocosms (600L tanks). To investigate habitat requirements, cabomba stems were freshly collected in the field and cultured in substrates varying in grain size, nutrient content and organic fraction. Cabomba fragments were also grown in culture solutions differing in nutrients and pH. Fragments of varying size were cultured to measure regeneration and colonisation potential. Some fragments were dried for different periods of time to establish survivorship after desiccation. A range of native aquatic macrophytes were planted alone and with cabomba together to investigate competitive interactions.

**Results/key findings**

The findings in this project showed that cabomba has very specific habitat requirements. The pH of the water is a strongly limiting factor, with cabomba preferring slightly acidic to neutral water with (pH6 – 7). Cabomba establishment and growth are greatly reduced in water with a pH above 8. Cabomba seems to satisfy most of its nutrient requirements from the substrate. Nutrient concentrations in solution were of less importance, indicating that cabomba will be able to establish well even in oligotrophic systems as long as there are sufficient nutrients available in the substrate. Cabomba growth was also influenced by substrate quality, with best growth performance observed in fine substrates with low organic content. These experimental findings corroborate field observations: cabomba infestations are predominantly found in soft water lakes with a slightly acidic to neutral pH and fine substrates, but there is no relationship with the trophic status (nutrient availability) of the water body.

Cabomba was able to regenerate even from single node stem fragments. About 50% of the tested fragments developed healthy new shoots. Regeneration success was not dependent on nutrient availability. However, establishment (rooting in substrate) was strongly dependent on fragment size. Single node fragments mostly failed to establish while fragments with four nodes or more (~10cm in length) had a high likelihood of establishment. Success of establishment was also linked to substrate quality (grain size). Cabomba was more likely to colonise tanks that had fine grained (sand) substrates while coarse substrates practically prevented cabomba from establishing.

**Implications for relevant stakeholders**

The detailed knowledge of habitat requirements will allow prediction of the future expansion of cabomba in Australia. Especially, it will permit identification of sites that are at increased risk of cabomba invasion, and therefore increased likelihood of timely detection and prevention of establishment. There is some scope for habitat manipulation to discourage cabomba establishment, for example through deposition of coarse gravel near boat ramps. This information will be of high value to managers of freshwater systems.

**Recommendations**

As there are currently no efficient control options available for cabomba, prevention of spread and establishment are key components for cabomba management.

**Communications**

**PRESENTATIONS**

Cabomba ecology and dispersal in Australia, National Aquatic Weeds Management Group meeting, Sydney, June 2011.

Aquatic weed ecology and management, War on weeds aquatic weeds forum, Noosa, June 2011.

Ecology of the submersed aquatic weed Cabomba caroliniana in Australia, 18th Australasian Weeds Conference, Melbourne, October 2012.

**PLANNED PEER REVIEWED PUBLICATIONS**

Regeneration and establishment of Cabomba caroliniana fragments, Aquatic Botany.

Desiccation and survival ability of Cabomba caroliniana fragments, Journal of Aquatic Plant Management.

Competitive interactions between Cabomba caroliniana and native submersed macrophytes, Freshwater Biology.

Habitat requirements of Cabomba caroliniana, Aquatic Botany.

(PRJ-006986)
Biological control of crofton weed on Lord Howe Island

Researcher/contact
Dr Louise Morin
CSIRO

What the report is about
This report presents a summary of research activities undertaken in 2011-12 to develop a self-sustaining and environmentally-friendly biological control program for crofton weed (Ageratina adenophora). The project was particularly targeted at Lord Howe Island (LHI), a World Heritage Area, but could also benefit ecosystems infested by crofton weed in coastal NSW and Queensland.

The prospects to establish an effective and safe biological control program for crofton weed in Australia are promising.

Where are the relevant industries located in Australia?
LHI is a world class international tourist destination. Ecotourism is an important source of revenue for the small community living on the island. The preservation of the natural environment, which is under continued threat from crofton weed, is therefore of prime concern. Furthermore, crofton weed colonises the restricted agricultural land present on the island and thus a reduction in infestations will protect the viability of the island primary production. Crofton weed is also a serious environmental weed in coastal regions of NSW and south-east Queensland that competes with threatened species.

Background
LHI is an island off the NSW coast, declared a World Heritage Area in 1982 in recognition of its outstanding natural beauty and exceptional biodiversity. It is, however, under serious threat from weeds. Crofton weed is one of the two dominant weeds on the island that has not been included in the eradication program implemented since 2004. The extent of its distribution, mainly in non-accessible areas, makes manual removal and herbicide control impractical. Biological control is believed to be the only viable option to reduce densities of crofton weed across its range on the island. A gall-fly and leaf spot fungus were introduced in Australia in the 1950s for the biological control of crofton weed, but have not had a substantial negative impact on weed populations on LHI and the mainland.

Who is the report targeted at?
This report will be of interest to the Board, residents and visitors of LHI who are the key stakeholders to benefit from the eventual release of an effective biological control agent against crofton weed. Land managers of coastal ecosystems in NSW and south-east Queensland will also be most interested in this future potential solution to manage more effectively crofton weed in their region.
Aims/objectives
The aim of this project was to perform the necessary research to develop a biological control program for crofton weed on LHI. Its specific objectives were to:

1. demonstrate that the crofton weed rust fungus, Baeodromus eupatorii (ex Mexico), does not pose a threat to closely-related non-target plant species in the family Asteraceae, including species endemic to LHI, and

2. gather baseline demographic data on crofton weed and associated vegetation to enable future monitoring of the impact of the fungus after its release.

Methods used
The crofton weed rust fungus was collected in Mexico and imported into the CSIRO high security quarantine facility in Canberra. Once a culture of the fungus was established, a series of trials were performed to investigate its host-range. The selection of non-target plant species for testing was based on molecular phylogenies of tribes in the family Asteraceae. Each species was tested in two separate trials (five replicates per trial) and crofton weed plants were used as positive control.

Four permanent 10m long transects were established through dense crofton weed stands at five monitoring sites on LHI to gather baseline plant demographic data. Percentage cover of crofton weed and other species was assessed in five 1m² plots along one side of each transect.

Results/key findings
Results from initial host-range testing on 37 closely-related species to crofton weed in the family Asteraceae, including the two Australian native Adenostemma spp. in the tribe Eupatorieae and a few endemic species from LHI, showed that the rust fungus is highly specific towards crofton weed. In these tests, it was capable of infecting only one other species, mistflower (Ageratina riparia), a close relative of crofton weed that is also an introduced weed in Australia. However, considerably less infection and restricted development of the fungus were observed on this species compared to that on crofton weed. These results are very promising as it is essential to demonstrate that the fungus does not pose a threat to non-target plants before permission can be obtained to release it in Australia.

Baseline plant community data collected at the five monitoring sites established on LHI showed that crofton weed severely limits the growth of other plant species. The introduction of a damaging biological control agent that will reduce the competitiveness of crofton weed is thus likely to result in a gradual shift of the plant community at infested sites.

Implications for relevant stakeholders
Without biological control, it is anticipated that the extent and impacts of crofton weed will only get worse on LHI, further threatening the integrity of this World Heritage Area and continuing to cause problems in the restricted land allocated to primary production on the island. Similarly, degradation of infested ecosystems in NSW and Queensland is likely to continue without biological control.

"The introduction of a damaging biological control agent that will reduce the competitiveness of crofton weed is thus likely to result in a gradual shift of the plant community at infested sites."

Recommendations
The prospects to establish an effective and safe biological control program for crofton weed in Australia are promising. The completion of host-range tests, initiated in this project, will be required to ensure a robust case exists before an application is put forward to the authorities for the release of the crofton weed rust fungus in Australia. Based on research performed so far, the fungus appears to be highly specific and no major hurdles in obtaining permission to release are foreseen.

Communications
Presentation: A poster presentation will be given at the 18th Australasian Weeds Conference, 8-11 Oct 2012, Melbourne.

PUBLICATIONS

Popular article on the project to appear in the winter or spring issue of the following newsletters: Friends of Lord Howe Island, Big Scrub Landcare, Bush Matters.

PLANNED PUBLICATIONS (PENDING ADDITIONAL FUNDING IS OBTAINED)

A scientific paper for a peer-reviewed journal will be produced when all testing is completed.

(PRJ-007026)
Genetic, reproductive and demographic facilitation of Sagittaria invasion

Researcher/contact
Dr Linda Broadhurst
CSIRO

What the report is about
This report is about genetic, reproductive and demographic research on the emergent aquatic weed Sagittaria. The focus of this project was to build a stronger understanding of this species biology to help focus the search for effective biocontrol agents.

Who is the report targeted at?
Local, State and Commonwealth Government weed control agencies, land managers and stakeholders, water infrastructure managers, weeds researchers.

Where are the relevant industries located in Australia?
Irrigated agriculture and water delivery infrastructure in Vic and NSW is most affected by Sagittaria invasion with risks now evident for Sydney, southern QLD, SA and southwest WA. Considerable resources are directed by various agencies and landholders to control Sagittaria every year, including over $2 million in the Murray Valley irrigation region alone. Irrigators, water resource and biodiversity managers, and government agencies across Australia will benefit from this research.

Background
Sagittaria is an emergent aquatic weed originating from southern regions of the USA and recently declared a Weed of National Significance (WoNS). Since first reports in 1959 near Brisbane, this aggressive invader has spread from the Sunshine Coast in Queensland to the Canning River in WA. Sagittaria significantly impacts irrigation-based agriculture and water-delivery infrastructure by rapidly and repeatedly blocking irrigation channels. It also threatens native biodiversity by choking waterways, changing water flow, availability and quality. The broad geographic range of Sagittaria and the intensity of invasion in south eastern Australia, indicate that eradication is no longer feasible and that new management strategies are required. Biological control is a realistic prospect for long-term and sustainable suppression of Sagittaria but the success of enemy release programs requires a robust understanding of potential agents and species biology.

Aims/objectives
This research will benefit:
1. weed and biocontrol researchers: by identifying regions in the USA where effective insects and pathogens are more likely to be found and where to deploy them in Australia,
2. land managers: by identifying seed production as a major leverage point for control, and
3. the Tri-State and WoNS Taskforces: in developing research and management priorities.

“There is a need to devise and trial methods aimed at controlling/limiting Sagittaria seed production that may include the timing of herbicide application, until a biocontrol agent is available.”
Methods used
Genetic: 25 USA and 23 Australian populations were genotyped to determine levels of genetic diversity, associations among populations, and identify the source of Australian infestations.

Reproduction: experiments to assess floral transition, display, pollinators and pollination, fertilisation and reproductive assurance were undertaken.

Biological control: 12 populations across NSW, Vic and WA and 16 populations in Texas and Louisiana were surveyed for the presence of phytophagous organisms, levels of herbivory and plant growth and reproductive performance.

Results/key findings
Genetic: genetic diversity was similar across Australian and USA Sagittaria populations suggesting that this weed has been introduced several times into Australia. Two geographic regions were identified in the USA (subtropical and temperate) whereas three groups exist in Australia. Populations genetically similar to both USA regions occur in Australia, but a distinctive third group of populations was found in Barmah Forest. Further exploration to unravel the origins of this third Australian group is required to determine whether this represents new genetic diversity being generated here, or represents introductions from outside the sampled USA range. These data highlight that broad sampling across the USA is required to find effective biocontrol agents for Australian Sagittaria.

Reproduction: several sexual mechanisms ensure high seed production in Sagittaria including plants being attractive to a wide range of pollinators, overlap in male/female flowering phases, and incomplete self-incompatibility that enhances seed production in the absence of other plants. These data indicate that seed production is a key leverage point for control.

Biological control: Australian Sagittaria were relatively free of insect and pathogen damage indicating an absence of potential biological agents in this country. In contrast, moths, beetles and flies were observed feeding on USA Sagittaria and several potential agents with a preference for Sagittaria fruit were identified. In contrast, leaf spot disease symptoms commonly found in the USA did not yield any fungal isolates specific to Sagittaria making them unsuitable as biological control candidates. Australian Sagittaria did not grow larger than USA plants, however, USA Sagittaria produced significantly less fruit and seed further suggesting that seed production is a major point of control for this weed.

Implications for relevant stakeholders
Industry: There is a need to devise and trial methods aimed at controlling/limiting Sagittaria seed production that may include the timing of herbicide application, until a biocontrol agent is available.

Communities: Educate communities that seeds are highly mobile and invasive dispersal agents enabling Sagittaria to invade new regions.

Policy makers: A co-ordinated cross-jurisdictional approach to Sagittaria management that includes identifying and prioritising source populations to prevent further infestations is required.

Recommendations
Genetic data suggest that broad sampling is required across the USA home range to find effective biocontrol agents for Australian Sagittaria and that further exploration of the origins of Barmah Forest populations is needed.

Seed production is a critical leverage point in the life cycle that should be exploited for the management and control of Sagittaria.

Further research is required on the biology and host specificity of natural enemies identified as high priority candidates for the biological control of Sagittaria in Australia.

Plant population modelling is required to 1) help prioritise potential biocontrol agents and 2) develop effective integrated management strategies for Sagittaria in varying habitats (natural and highly-disturbed water ways).

Communications
Bryant: Honours Research Proposal, Botany Department La Trobe University (2 Sept 2011).
Bryant: Honours Poster, Botany Department, La Trobe University (17 February 2012).
Broadhurst: CSIRO Factsheet: “Improving the control of Delta Arrowhead (Sagittaria platyphylla)”
Hoebbe and Edwards: Final report to CSIRO: The potential and realised mating system of Sagittaria platyphylla (May 2012).
Kwong: Organised the ‘Aquatic Weeds Symposium’, La Trobe University (7 April 2011).
Kwong: Poster presented at the XIIth International Symposium on Biological Control of Weeds, Hawaii (11-16 September 2011).
Kwong: Project update presented to key DPI, DSE and external stakeholders at a Weeds Research and Investment Program meeting, Melbourne (24 May 2011).
Kwong: The natural enemies associated with Sagittaria. Presentation, La Trobe Botany Retreat, Healesville (11-13 July 2011).
Kwong and Broadhurst attended the Sagittaria Weeds of National Significance workshop, Albury NSW (19 April 2012).
Kwong: presentation will be made at the International Conference on Advances in Plant Sciences, Thailand (14-18 November 2012)

(PRJ-007053)
Expanding the aquatic herbicide list: a proactive approach

Researcher/contact
Mr Joseph Vitelli
DEEDI

What the report is about
This research is aimed to improve the chemical options available to managers entrusted with managing aquatic ecosystems. Toxicity indices were assigned to a suite of chemicals potentially suitable for aquatic use. The calculated indices provide a tool for researchers and decision makers to compare, prioritise and short list new actives to reduce adverse effects on aquatic systems. The review of national and international legislation on aquatic herbicides proposes guidelines that may lead to the development of national consistencies across states and territories on the use of agricultural chemicals for aquatic situations.

Who is the report targeted at?
Report is targeted at staff entrusted with managing aquatic ecosystems from federal, state and territory governments, local government agencies, lifestyle farmers, agriculture, pastoral, NRM groups and water authorities.

Where are the relevant industries located in Australia?
The report will assist operational staff (having the right chemicals to do the job), policy makers (a more informed database to draw information from) and researchers (evaluating new products on efficacy and risk to off-targets and having an improved small scale trial permit for aquatic use) that are involved in aquatic weed management throughout Australia.

Background
The nation’s capacity to respond to aquatic weed biosecurity risk issues is hindered by a lack of available tools, in particular registered herbicides for aquatic weed management. Herbicides are acknowledged as the primary tool of control and a vital component of all integrated aquatic weed management strategies. In Australia, aquatic weed managers have been limited to the use of 13 registered herbicides (three are under a minor use permit) for aquatic areas, three herbicides for irrigation and drainage channels and one herbicide for estuaries and inlets (under a minor use permit). Many of these herbicides have been used since the 1950s. With the development of new formulations and chemistry, options now exist that not only provide safer alternatives but actives that are more efficacious on the new aquatic weed species entering Australia. The advent of aquatic plant resistance also strengthens the need for additional management tools and the need for new herbicides for resistance management.

The identification of 12 actives with new formulations and chemistry that are safer, pose reduced risk to aquatic organisms and improve the control of many floating, submerged and semi-terrestrial aquatic weeds.
**Aims/objectives**

Through input from key individuals in state and federal agencies involved in aquatic weed management, project aimed to investigate potentially new and safer herbicides, improve efficacy and efficiency of existing herbicides, develop herbicide risk assessment to reduce adverse effects on aquatic systems and in the long-term integrate methods that reduce reliance on chemicals.

**Methods used**

1. **Review of state and federal legislation.** A review was undertaken of Australian state and federal legislation and legislation from overseas (United States of America, Canada, New Zealand and Europe) legislation pertaining to environmental and chemical use in aquatic situations, with the aim to develop guidelines leading to national consistency for the use of agricultural chemicals in aquatic systems.

2. **Workshop.** Invite key individuals from state and federal agencies involved in aquatic weed management to outline aquatic weed issues, promote the interchange of information on aquatic weed problems, stimulate and encourage members to contribute items of information on aquatic weeds, encourage researchers working in similar fields to form working groups to consider specific topics and to develop and maintain contact with other organisations with similar interests in aquatic weed management.

3. **Herbicide list.** The network reference group developed a list of herbicides that can be used in aquatic systems and reviewed data limiting their approval in Australia.

4. **Develop a best practice framework.** Undertake a risk analysis of chemicals used in aquatic systems.

5. **Focus group.** The establishment of a stake-holders network reference group to function post May 2012, as an advisory group to the National Aquatic Weed Management Group on issues pertaining to aquatic weed management.

**Results/key findings**

Project key findings were:

1. A set of guidelines on the use of agricultural chemicals in aquatic systems aimed at developing national consistencies;

2. An improved and standardised process for undertaking small scale aquatic weed research to better protect the environment, leading to a streamlined process for the issuing of aquatic minor use permits;

3. The identification of 12 actives with new formulations and chemistry that are safer, pose reduced risk to aquatic organisms and improve the control of many floating, submerged and semi-terrestrial aquatic weeds.

**Implications for relevant stakeholders**

Expanding the list of approved aquatic herbicides for use in Australia would delay the risk of aquatic plants developing resistance by reducing the pressure of only using a few herbicides and provide safer alternatives. Effective control of these weeds will prevent weed dominance that is often associated with aquatic weeds and thereby increase aquatic biodiversity. The guidelines proposed from the legislative review will hopefully contribute towards achieving national consistency so that future aquatic weed control programs are compliant with environmental legislation in all states and territories. If consensus is achieved adoption should be fast amongst aquatic weed managers. Also through extension activities, help restore community confidence that safe aquatic herbicides are in use and a necessary tool in integrated aquatic weed management.

**Recommendations**

A report documenting an expanded list of 12 herbicides suitable for aquatic use will be submitted to APVMA. The proposed herbicides will reduce off-target damage, improve efficacy and better manage aquatic weeds nationally. The aquatic small scale experimental permit submitted to APVMA will provide researchers a more consistent experimental approach for dealing with complex aquatic weed issues, leading to a more streamlined process for the issuing of minor use permits. The key findings of the project will also be delivered through workshops, presentations at appropriate meetings, and through structured and informal interviews with aquatic weed managers. The on-going national stakeholders group will continue to ensure a consistent approach to chemical use in aquatic systems and will be facilitated through the National Aquatic Weed Management Group. This stakeholders group will be a conduit to deliver up to date information pertaining to aquatic herbicides to the appropriate agencies in each state and territory. APVMA will be able to also use the report findings to assist with future aquatic herbicide registrations.

**Communications**

Two papers (“Expanding the list of aquatic herbicides for use in Australia - Stop, Pass or Go?” and *A Brief Overview of International Pesticide Regulation*) are flagged for potential publication in *Plant Protection Quarterly*.

(PRJ-007062)
Further biological control of alligator weed (*Alternanthera phylloxyroides*) is needed to control the semi-aquatic and terrestrial infestations of this weed of national significance (WoNS). Before this project, a suite of potential biocontrol agents of alligator weed had been identified but lacked thorough assessment. To address this, the host specificity of the remaining insect agents was tested in Australian quarantine and in the native range. Observations on the efficacy of these agents were also made in the field and in the laboratory. Unfortunately none of these insects proved sufficiently specific for release in Australia for control of this invasive plant. Furthermore, these agents do not inflict high levels of damage to the plant in the field. Searches were conducted for a pathogenic fungus *Uredo pacensis*, but it was only found sporadically at one site in Bolivia.

We have exhausted the prospects for developing further biocontrol agents of alligator weed and can conclude that no realistic opportunities remain.

---

**Who is the report targeted at?**

Groups and individuals who have responsibility for managing land or water resources, particularly waterways, wetlands, floodplains and irrigation systems, on the east coast of Australia. This includes state agencies, councils, water corporations, and private landholders.

**Where are the relevant industries located in Australia?**

Alligator weed is a serious aquatic weed along the east coast of Australia. It is particularly problematic in the lower Hunter Valley in NSW. It was declared a WoNS because of its potential to spread and invade, its impact on the environment and agriculture (irrigation systems) and the lack of control methods. Aquatic populations of this weed are already under good biocontrol but land managers would greatly benefit from new agents that attack the semi-aquatic and terrestrial infestations.

“We have exhausted the prospects for developing further biocontrol agents of alligator weed and can conclude that no realistic opportunities remain.”
Background
Alligator weed has been the subject of a biocontrol research since the 1960s. During the 1970s a number of agents were introduced to various countries experiencing a problem with this weed, including Australia. One agent, the flea beetle provided excellent control in aquatic habitats, but not semi-aquatic and terrestrial zones. New surveys began in 2001 and a number of new agents were discovered. Four of these were tested in an earlier project and shown to be unsuitable under the very high standards of host specificity now required. In particular, the native species of Alternanthera were attacked by all of these agents. Four other insect agents and one fungal pathogen still required assessment of their host specificity which is the aim of the research project reported here.

Aims/objectives
Conduct detailed host specificity studies on two potential insect biological control agents in Brisbane quarantine and another two insect species in Argentina; and examine the distribution and conduct preliminary host specificity testing on one potential fungal biological control agent.

Methods used
Locate and collect insects and fungus in the field in Argentina. Transport them to Australian quarantine or the Argentinean laboratory. Rear the organisms to supply a reliable source of material. Test organisms for host specificity by exposing them to related plant species and observe their use (oviposition, feeding, damage) of the various plant species. Record other relevant aspects of the biology of each species and produce a written report of each species.

Results/key findings
Two insect species were successfully tested in an Australian quarantine laboratory, the flea beetle Phenrica sp. poss. litoralis, and the stem galling fly, Ophiomyia marelly. Both species feed and develop on various Australian native species of Alternanthera and other genera and so are not specific to alligator weed and should not be released.

The remaining two fly species, Ophiomyia alternantherae and Ophiomyia buscki, proved to be very difficult to collect in the native range. Towards the end of the project, O. buscki was finally collected and subject to preliminary testing. Adults only oviposited on alligator weed and not the test plants, suggesting that it could be host-specific. However, it caused little damage in the field or laboratory and therefore is unlikely to be an effective agent.

"Land and water managers cannot rely on further agents for biocontrol of alligator weed becoming available. Instead they need to explore other methods of managing alligator weed, including optimization of existing established biocontrol agents."

Ophiomyia alternantherae appeared to be even less damaging. We therefore cannot recommend that these species for further development as biocontrol agents.

The rust fungus proved to be highly elusive. Despite many years of incidental searching and the focussed primary searching in the current year of this project in eco-climatic areas similar to the original site, it has only been found at one site in Bolivia, and even there it was only sporadically present. Exports permits cannot be obtained from Bolivia. The geographic restriction of this rust to one country where it cannot be exported hampers efforts to test this species and also raises questions about its probable effectiveness in Australia.

Implications for relevant stakeholders
Land and water managers cannot rely on further agents for biocontrol of alligator weed becoming available. Instead they need to explore other methods of managing alligator weed, including optimization of existing established biocontrol agents.

Recommendations
Terminate the search for new alligator weed biocontrol agents. Further funding of new agents for alligator weed is unlikely to produce benefits.

Communications
Supporting evidence in the form of reports from Argentinean contractors and reports of host specificity were provided off-line to RIRDC.

Media release was provided off-line to RIRDC.

Scientific publications on the assessment of the agents considered in this report will be produced, in particular: Biology and host specificity of eight insects considered for biological control of alligator weed. Schoeller et al. Environmental Entomology.

(PRJ-007123)
Manipulating weed successions when restoring native vegetation communities

Researcher/contact
Mr Malcolm Taylor
Agropraisals

What the report is about
Maintaining, regenerating and restoring native vegetation in Australia proves particularly challenging, given the scale involved, the limited resources for such activities and the constant invasive pressure of exotic weed species. Techniques for direct seeding of native vegetation have dramatically improved in the past two decades with the development of dedicated seedbanks and efficient minimum tillage seeders. Managing plant successions along seeding lines remains difficult as suppression of weed growth with glyphosate alone is a short term measure that inevitably leads to a flush of new competitive weeds.

This project identifies residual herbicides that will suppress exotic weeds for sufficient time to enable native seedlings to establish successfully in the Riverina region of New South Wales.

Who is the report targeted at?
Public lands managers and those with a professional interest in re-establishment of native vegetation.

Where are the relevant industries located in Australia?
Revegetation of degraded sites with native vegetation is conducted in all states of Australia, mainly by publicly-funded catchment management, national parks and forests authorities.

Background
Regeneration of local endemic vegetation can often be impaired by severe competition from exotic weeds. Historically, many good examples of a successful strike of native seedlings have been overwhelmed with a vigorous competitive onslaught of weeds such as Paterson’s curse, annual ryegrass, wireweed, fleabane, Bathurst burrs etc. Simultaneous spraying of glyphosate either side of the drill line when seeding natives has become standard practice for Murray Catchment Management Authority (CMA) staff. This enables moisture, nutrients and light to be conserved and maximised for the native seedlings, whilst minimising physical disturbance that could lead to denudation and erosion. The effect is temporary, however, and a second cohort of weeds will re-establish along this spray line, again competing vigorously with the young established native vegetation (albeit at a later timing).

Residual herbicides have long been sought that may defer re-colonisation of the drill lines with exotic weeds. Identifying residual herbicide treatments that can be applied simultaneously when seeding mixed native species is a difficult task because multiple genera are being sown with broadly differing herbicide tolerances, soil types will vary in texture, soil moisture, organic matter content, pH, surface trash and vegetation cover and follow up moisture may not be available to carry the applied herbicide into the soil surface where it could be available for weed uptake.

Despite all of these challenges, the act of displacing a narrow band of treated surface soil away from the seed by using a narrow point opens up opportunities to use residual herbicides that would otherwise be phytotoxic to the native species being sown.
Aims/objectives
Development, demonstration and adoption of simple, effective and affordable methods of weed management to enhance the establishment, growth and survival of native vegetation by direct seeding.
Specifically we sought to identify residual herbicide treatments that would selectively suppress exotic annual weeds whilst enabling native vegetation to establish after direct seeding with minimal soil disturbance.

Methods used
Replicated field trial sites were established at Wakool, Mathoura, Conargo and Cobram in collaboration with Martin Driver from the Murray CMA. All sites were located on ex-farming ground that was to be re-allocated to native vegetation. Herbicide treatments were hand sprayed at each site perpendicular to the lines of seeding of native vegetation. Treatments included various rates of simazine, oxyfluorfen, chlorosulfuron, isoxaflutole, pendimethalin, flumetsulam and sucrose; mostly tank mixed with glyphosate to control emerged pasture and/or weeds.

Seeding was conducted with a KB trailed seeder fitted with a coulter, narrow point and presswheel that displaces a narrow strip of treated soil away from the seed row. Assessments were made of weed control using a linear scale of 0-100 as percentage control or percentage ground cover. Western black wattle population densities were measured by counting seedlings along five 2.5m lengths of drill line per plot in early summer 2011 and also total seedling numbers per plot in autumn 2012.

Results/key findings
Simazine, terbutryne, chlorosulfuron, flumetsulam, pendimethalin, oxyfluorfen and sucrose treatments did not offer any discernible advantage to the establishment of western black wattle.

By contrast, three treatments exhibited promise; namely isoxaflutole, imazethapyr and halosulfuron as each resulted in effective weed control with improved western black wattle seedling survival and vigour. Results with these latter three treatments were sufficiently encouraging to warrant tentative field testing in large scale plantings by the Murray CMA.

Implications for relevant stakeholders
Adoption of narrow point, minimum till drills coupled with simultaneous application of glyphosate ahead of the drill has markedly improved the success rates for direct seeding of native vegetation. This lowers the cost of the operations and improves the efficiency of seedbank utilisation. Adoption of the findings of this project will encourage increased use of direct seeding for habitat restoration, if the results can be replicated across a broader range of native species. Improved seed placement can be integrated with effective pre and pre-emergent herbicide applications to enable large scale direct seeding to be conducted confidently by community lands managers.

Recommendations
Catchment Management Authorities ought to further evaluate and adopt the techniques described in this report that have been pioneered by Martin Driver, his Murray CMA team and their predecessors.

Further evaluation is required to field test the tolerance of a broader range of native vegetation species to imazethapyr, halosulfuron and isoxaflutole herbicides applied prior to seeding with a no-till drill.

Communications
An extension article was prepared for the Murray CMA landholder newsletter, a trial inspection organised for CMA staff and a full report submitted to RIRDC for publication. (PRJ-007145)
How do decisions by stakeholders affect weed distribution at a landscape scale

Researcher/contact
Dr Yvonne Buckley
University of Queensland

What the report is about
This report summarises the motivations of stakeholders to control serrated tussock (Nassella trichotoma). Land managers were asked what economic and social factors motivated them to control serrated tussock. Landholders were also surveyed for data for Parthenium (Parthenium hysterophorus) and Branched broomrape (Orobanche ramosa) and a model for Chilean Needle grass (Nassella neesiana) and African Lovegrass (Eragrostis curvula) was constructed. The focus of this report is on results for serrated tussock (over 100 online surveys completed and 15 phone interviews).

Who is the report targeted at?
The report is aimed at those who engage stakeholders to control agricultural weeds - land owners (private and government), council weed officers, state and federal government officers.

Where are the relevant industries located in Australia?
Serrated tussock displaces palatable pasture grasses, native habitats and can infest entire properties. It currently affects 2 million hectares of land in Northern/Southern NSW tablelands, Southern Victoria and South-east Tasmania. Serrated tussock affects commercial graziers by reducing productivity and non-commercial farms, who are legally obliged to control it.
Background
People’s motivations to control weeds are an important aspect of landscape scale weed control. Motivations help to predict who will control a weed and when they might be unwilling to do so. Information about motivation can also be useful in targeting education and awareness campaigns. In this project a model was developed to see how variability in decisions by multiple stakeholders can affect weed spread at a landscape scale and how best to implement management strategies based on this knowledge.

Aims/objectives
The aim was to collect data on the social and economic incentives to control weeds. One important aim was to see if different land managers are motivated by different factors to control the same weed, and what might predict those motivations.

Methods used
Engagement with landholders was undertaken through online surveys or structured interviews. Contacts with landholders were arranged through consultation with the relevant weed officer or researcher.

Results/key findings
Protecting productivity was the most important motivation to control serrated tussock for sheep farmers. For cattle farmers, conservation land managers, and people whose main income was off farm, the 95% confidence intervals show legal and moral reasons give a similar level of motivation, with protecting productivity tending to be a slightly weaker. A second analysis shows that sheep farmers tend to have a different set of motivations than other enterprises. Surprisingly, cattle farmers and conservation land managers tend to have similar sets of motivating factors.

Implications for relevant stakeholders
Land managers are motivated to control weeds not only to improve their farm productivity and a legal requirement, but also because they feel a social responsibility. Differences in motivations between sheep farmers and cattle farmers and conservation land managers (who have similar motivations) could help target awareness and education campaigns about serrated tussock.

The action of neighbours does not generally affect land managers’ motivation to control weeds but can be a high priority for certain people who border badly infested areas. Most respondents who commented said words to the effect “it would be nice if the neighbours did control, but I choose to control irrespective of what they do”.

Recommendations
When attempting to engage people to control a weed, take into account that different enterprises will be motivated by different sets of factors, and use this target engagement more effectively.

Communications
PRESNETATIONS
South East Queensland Pest advisory Forum, Beaudesert, 12 December 2011, Keynote at Weed Management Society of South Australia Conference, 8-9 May 2012.

Planned peer reviewed publications The behavior of multiple independent managers and ecological traits interact to determine prevalence of weeds (in review with Ecological Applications); Optimal weed control with multiple weed managers (to be submitted to Journal of Applied Ecology).

(PRJ-006998)

“ Land managers are motivated to control weeds not only to improve their farm productivity and a legal requirement, but also because they feel a social responsibility. Differences in motivations between sheep farmers and cattle farmers and conservation land managers (who have similar motivations) could help target awareness and education campaigns about serrated tussock. ”
Biological control of Hudson pear in Australia

Researcher/contact
Mr Royce Holtkamp
NSW Department of Primary Industries

What the report is about
This report is about the quarantine host specificity testing of a number of biotypes of the cochineal insect Dactylopius tomentosus to determine their suitability as biological control agents for Hudson pear, Cylindropuntia rosea, and other members of the cactus genus Cylindropuntia.

Who is the report targeted at?
The information in this report will be of interest to the Federal agencies, DAFF (Biosecurity Australia) and DSEWP&C who decide on suitability of new biological control agents for release in Australia and to land managers who deal with the infestations of Hudson pear and other Cylindropuntia species.

Where are the relevant industries located in Australia?
The main infestations of Hudson pear are in north-western NSW. Smaller infestations have been reported from Victoria, South Australia, Western Australia, Queensland and the Northern Territory. Estimates of the area of NSW infested range from 60,000 to 100,000 hectares. Hudson pear has the potential to colonise large areas of inland Australia including the Darling River basin.

Background
Hudson pear was introduced into Australia many years ago as an ornamental species and has subsequently naturalised in north-western NSW and several other Australian states. It is extremely invasive and has long, sharp spines capable of injuring humans, stock, working animals and wildlife. The plant also adversely impacts on biodiversity. A biological control program was initiated for this plant in 2009 with an application to Australian Weeds Committee for approval to list Hudson pear as a target species for biological control.

Approval for a host testing list and import into Australian quarantine was obtained the same year from Biosecurity Australia. Funding from Western CMA and I&I NSW enabled searches to take place in Mexico for a strain of cochineal insect specific to Hudson pear. This insect was imported into quarantine in August 2010 and is currently being cultured and increased for host specificity testing.
In light of the results of host range testing conducted to date, an application will be made to the Australian Weeds Committee to list all eight Cylindropuntia spp. naturalised in Australia as target species for biological control. All Cylindropuntia spp. are weeds of varying distribution and severity in Australia and control programs for these species would benefit from the addition of viable biological control agents.

Aims/objectives
To finish quarantine host specificity testing for a strain of the cochineal insect Dactylopius tomentosus which is specific to Hudson pear and submit an application for approval to release to Biosecurity Australia. To conduct searches in Mexico and South Africa to determine if additional strains of cochineal insects exist which may also be suitable for importation to Australia for further testing. The sectors most likely to benefit from this work are the agricultural industry, primarily sheep and cattle graziers and environmental protection agencies.

Methods used
The original Mexican cochineal culture was increased and subjected to Biosecurity Australia approved host specificity testing procedures. In addition, two extra biotypes from Australia and South Africa were also included in the testing. These tests included choice and no choice tests to validate that the species is host specific to Hudson pear and other members of the genus Cylindropuntia and will not impact on any other native plants and agricultural or ornamental species. Several members of the genus Cylindropuntia were also DNA tested using plastid and genomic markers to investigate genetic similarity between Australian (Qld and NSW) samples and those of the native range in Mexico, and to confirm the identity of the Australian samples to aid in verification of host specificity.

Results/key findings
Host range testing of the Australian biotype has shown that it is compatible with Australian populations (from Grawin and Lorne, Qld) of C. rosea, the Spanish and Mexican C. rosea and Australian populations of C. fulgida var. mammilata and C. imbricata. There was little compatibility with Australian populations of C. leptocaulis, C. prolifera, C. spinosior, C. tunicata or the C. rosea population collected from Cracow. This biotype may therefore be a potential biological control agent for C. rosea, C. fulgida and C. imbricata in Australia. Because it is already naturalised in Australia it does not require approval to release it in New South Wales or Queensland.

Host range testing of the Mexican biotype has indicated that this population will not attack any of the Australian or Spanish populations of C. rosea giving a clear indication that there are taxonomic issues with the species C. rosea. Insects of the Mexican biotype have developed on C. kleiniae, C. imbricata, C. fulgida var. mammilata and even C. spinosior (though less compatible). This biotype may therefore be a potential biological control agent for these species.

Host range testing of the South African biotype has not been concluded. However results so far indicate good activity against C. rosea collected from Mexico and Cracow but not those collected from Grawin and Lorne. Good activity has also been indicated on Australian populations of C. imbricata, C. fulgida var. mammilata and C. kleiniae. Of the three biotypes under test, this South African biotype appears the most vigorous. This biotype has been released in southern Africa where it is proving to be an outstanding biocontrol agent for C. fulgida.

In light of the results of host range testing conducted to date, an application will be made to the Australian Weeds Committee to list all eight Cylindropuntia spp. naturalised in Australia as target species for biological control. All Cylindropuntia spp. are weeds of varying distribution and severity in Australia and control programs for these species would benefit from the addition of viable biological control agents.

Implications for relevant stakeholders
Control of Hudson pear is currently extremely difficult and reliant on conventional techniques such as herbicide application. The type of terrain and vegetation in which infestations occur makes this extremely difficult. A biological control agent would allow an integrated control approach.

Recommendations
Recommendations for this report are to target persons conducting control operations on Cylindropuntia species.

Communications
When all host specificity testing is completed an application for release will be submitted to Biosecurity Australia and a research paper will be submitted for publication in the journal Biological Control.

(PRJ-007013)
Climate change and the risk of weed invasions in the Murray Darling Basin

Researcher/contact
Dr Rieks van Klinken
CSIRO

What the report is about
This report describes research aimed at predicting habitat suitability across the entire Murray Darling Basin (MDB) for three key weed threats, lippia, parthenium and Chilean Needle Grass (CNG). In so doing it demonstrates for the first time that it is possible to incorporate a wide range of fine-scale drivers such as flooding regimes, land use, and land management practices into such predictions.

Who is the report targeted at?
This project was centred on the Murray Darling Basin, but is of national importance. The target weeds together threaten much of Australia, and impact a wide range of stakeholders including the pastoral industry, environment and human health (parthenium). However, of broader significance is the modelling approach that we have developed. It provides the basis for developing regional to national scale strategies for managing our worst invaders. This is because the approach allows predictions to be made at a wide range of spatial scales, and for a wide range of management and climate change scenarios.

“Reliable predictions of potential distribution and spread of invasive species is critical to their effective long-term management. The research supports this, and also demonstrates that reliable predictions can be readily made with available software.”

Background
In this project predictive models will be applied across the entire Murray Darling Basin. This will involve expanding the spatial data set, including overcoming issues relating to inconsistent layers across jurisdictional borders, and the much larger data set. Model building will be conducted through expert workshops. This will involve developing models for new species (Chilean Needle Grass) and adjusting model structures and parameters of existing models (lippia and parthenium). The effect of climate change will be modelled as both direct effects (through changing temperature and soil moisture) and through altered flood regimes (MDB-Flood Inundation Model, Overton et al., 2009). Changes in land use will be modelled to reflect different management strategies and various farming options. Scenario analysis will be undertaken to determine how different climate scenarios and different environmental flow regimes affects risk of invasion (habitat suitability) at the enterprise, subcatchment and regional level.

Validation work is critical in giving confidence in predictions, especially with such a new modelling approach, and to address concerns regarding heavy reliance on expert opinion. The collaboration with QUT and field survey work will be critical in achieving this. Validation will be conducted through model testing and through structured field survey with the aim of testing different sources of potential error or uncertainty. QUT will assist in developing the methodological approaches for testing for the wide range of possible types of uncertainty, and in analysing and synthesising results.

Aims/objectives
Development and demonstration of an innovative approach to predicting potential weed distributions.
Methods used
The three modelled weeds were lippia, parthenium and CNG. A model was developed for each species to predict habitat suitability, habitat susceptibility and response to climate change, changes in land use and management. Models were developed through a series of expert workshops held in Queensland and Victoria. Models combined process-understanding obtained from experts (researchers, landholders, weed managers and natural resource managers) with output from existing bioclimatic models, and data obtained from field validation work. Modelling was done using Bayesian Belief Networks and the results incorporated within a Geographic Information System. Considerable effort was also spent categorising the different types of possible error in the model predictions, and on testing this through field work and a range of analytical techniques.

Results/key findings
The expert elicitation process was streamlined to capture the information required to develop a predictive model. In most cases, field validation supported the process-understanding of experts. However, some important knowledge gaps were identified, especially in relation to the competitive ability of new populations.

A methodology was developed to handle fine-scale data across the Murray-Darling Basin. This entailed a staged development of handling nearly 3.3 million hectares of 25 m² pixels that originally took 55 hours to run using Python script, but with adjustments and removing redundancies, was reduced down to two hours within the ESRI ArcGIS environment.

It was predicted that the Darling River system and associated wetlands will remain highly suitable for lippia regardless of the climate scenario. Highly suitable habitat for CNG is expected to retract irrespective of climate change scenario, but the effect will be greatest under a drying climate. Large areas in both the northern and southern ends of the MDB are currently suitable for parthenium. This is expected to remain much the same under a wetter climate scenario, but retract dramatically under a drier scenario. The risk of invasion from existing populations (habitat susceptibility) was also modelled for CNG and parthenium. Most areas that are highly suited to CNG under each climate scenario were predicted to be under immediate risk of invasion, although dispersal rates may have been overestimated. In contrast, the most immediate risk of invasion by parthenium remains in the north. The effect of different management scenarios was also modelled. Lippia was sensitive to flood regimes, land use change and grazing management. CNG invasions were predicted to be sensitive to vehicle hygiene, but not to grazing management, although field validation data suggests that habitat suitability may be more sensitive to grazing management and slashing than currently thought. Habitat suitability for parthenium was sensitive to grazing management, although the strength of this relationship also requires further field testing.

Implications for relevant stakeholders
General implications of modelling were specific for each case study weed. The best opportunities for managing lippia will be through minimising opportunities for establishment. Modelling identified areas for strategic management of parthenium (including the southern MDB), and highlighted the importance of grazing management practices in minimising habitat suitability. Further study of CNG (and to a lesser extent parthenium) is required, especially on the role of competition and of slashing in facilitating invasions. This will be critical for properly quantifying the risk this species poses, and for strategically managing those risks across its potential distribution.

Recommendations
Current predictions of potential distribution, on which national and other strategies are based, rely solely or primarily on climate. They therefore do not include other important drivers of invasion success, and are insensitive to changes in land-use, land management practices, flooding regimes and other factors. Reliable predictions of potential distribution and spread of invasive species is critical to their effective long-term management.

The research supports this, and also demonstrates that reliable predictions can be readily made with available software. Predictive modelling aimed at capturing the effect of all key drivers of invasions should therefore underpin the development of national, state and territory and regional scale weed management strategies.

Communications


Murray JV, van Klinken RD. How useful is expert knowledge helpful when predicting weed invasions in novel environments? Diversity and Distributions. In draft.


Expert workshops in Toowoomba and Benalla (Chilean needle grass), Mitchell (parthenium) and Goondiwindi (lippia).

(PRJ-007016)
A microwave system to kill weed seedlings without herbicide

Researcher/contact
Dr Graham Brodie
University of Melbourne

What the report is about
Interest in microwave treatment as part of a weed control strategy has increased because of the rapid development of herbicide resistant weed biotypes and the growing evidence that herbicides are impacting human health and a number of key species such as frogs and marine creatures, in natural ecosystems.

Who is the report targeted at?
This report will be of interest to all practitioners who need to manage weeds when herbicide options may be limited or prohibited.

Where are the relevant industries located in Australia?
Microwave weed management may be applied throughout Australia to manage weeds in agricultural enterprises, on public land, within municipal jurisdictions, in various sporting facilities and by landscape gardeners. A smaller 1 - 2 kW unit could also be designed and developed for use by householders.

The industries that may gain immediate benefit from microwave weed management technologies include: intensive horticultural enterprises (both paddock based and in greenhouses for soil and potting mix pasteurisation to control weeds and soil born pathogens), turf curators, municipalities and government authorities that manage weeds in environmentally sensitive areas or near municipal water supplies, broad-acre croppers, and landscape and domestic gardeners.

Background
Interest in the effect of high frequency waves on plant material began in the 1920’s. Many of the earlier experiments on plant material focused on the effect of radio frequencies (RFs) on seeds in the soil; however recent studies have shown that microwave treatment of emerged seedlings is much easier than treating seeds in the soil.
The objective of this research was to design, fabricate and test a system that can focus microwave energy at ground level to kill weeds. Practitioners from the broad-acre cropping; production and amenity horticultural; and natural resource management sectors will directly benefit from this project. There may also be indirect benefits to ecotourism and human health services as herbicide exposure is reduced through the adoption of this technology.

Methods used
Extensive consultation with national and international microwave experts was undertaken during the project. A computer simulation, using the Finite Difference Time Domain (FDTD) technique to solve Maxwell’s Electromagnetic equations in a complex 3-D space, evaluated various design concepts that might be considered as a microwave weed killing device. The more promising design concepts were fabricated and tested on an 1 kW prototype system built from a modified microwave oven with a wave-guide fed from the oven’s magnetron.

The 1 kW prototype system was used in various experiments at Dookie campus of the University of Melbourne and at the Tropical Weed Research Station in North Queensland to demonstrate the technology’s ability to kill weed plants and their seeds in soil. Finally, based on the evidence from these simulations and experiments, an 8 kW, trailer mounted, microwave weed killing device was designed, built and tested at the Dookie Campus of the University of Melbourne.

Results/key findings
Microwave treatment kills weed plants and their seeds, as outlined in the recently published papers listed below. Treating plants requires much less microwave energy than treating seeds in the soil. The most effective way of applying microwave energy to weeds is via a horn antenna array. These antennae focus microwave energy onto plants and the soil in the same way that a “spot light” focuses visible light, allowing individual plants to be treated without affecting their near neighbours. Irreversible wilting and subsequent plant death occurs within one or two seconds of microwave exposure, depending on the applied microwave power.

The final trailer mounted prototype has an array of four horn antennae, each delivering 2 kW of microwave power to the soil surface.

Implications for relevant stakeholders
Microwave treatment is immediate, chemical free, and leaves no residue at the treatment site. Treatment can take place irrespective of the prevailing weather conditions and there is no withholding period needed at the site once treatment is completed. Microwave treatment also reduces the number of pathogenic organisms in the soil and increases the rumen digestibility of treated plant materials, such as ryegrass or crop stubbles, by about 10%. This may have interesting benefits for mixed enterprise farms.

The embodied energy of microwave treatment is higher than that of chemical treatments; however it kills herbicide resistant biotypes and can provide some secondary benefits as mentioned earlier.

Recommendations
There have been a number of enquiries from industry about the usefulness of microwave treatment to: manage infestations of snails in cropping areas; increase the biodegradation of crop stubbles because of the enhanced digestibility of microwave treated plant material; and improve the wet-ability of hydrophobic soils through the volatilisation of hydrophobic compounds in soil using microwave heating. These problems should be investigated through an ongoing research programme using the new 8 kW prototype system.

Communications

SELECTED MEDIA ARTICLES
http://www.grdc.com.au/director/events/groundcover.cfm?item_id=BO88BC99730F98EAE70D82D851e6O7C8article_id=CB9E88BC9F8169F78C7C54D309D89D0
(Prj-006867)

Irreversible wilting and subsequent plant death occurs within one or two seconds of microwave exposure, depending on the applied microwave power.
Biocontrol of prickly acacia: host specificity testing of new agents from India

Researcher/contact
Dr Kunjithapatham Dhileepan
DEEDI

What the report is about
The report is about the importation and host specificity testing of two insects from India as biological control agents for prickly acacia (Acacia nilotica subsp. indica), a major weed in the natural grasslands of northern Australia.

Who is the report targeted at?
The report will be of interest to:
1. Graziers and land managers in northern Australia
2. Meat & Livestock Australia
3. Environmental conservators
4. National Prickly Bush Management Group
5. State Government agencies - Qld, WA and NT, and
6. Weed management researchers in Australia and overseas (e.g. Indonesia).

Where are the relevant industries located in Australia?
Prickly acacia, a Weed of National Significance, is widespread throughout the grazing areas of western and coastal northern Queensland, the Northern Territory and Western Australia. In Queensland over 7 million ha and 2,000 km of bore drains are infested with prickly acacia.

Background
The northern beef industry is seriously affected by prickly acacia and biological control is the only long term sustainable management option. Though the biological control of prickly acacia has been in progress since the 1980s, the need for effective agents continues to be a priority, as those already introduced have either failed to establish, or are as yet ineffective. Australian populations of prickly acacia have been determined to be of Indian origin. The majority of the regions in India are also climatically similar to northern Australia. Hence, native range surveys were conducted in India from 2008 to 2011. In India, five species of insects and two rust fungi were identified as potential biological control agents for prickly acacia. Two of the prioritised insects, a stem-feeding scale insect (Anomalococcus indicus) and a leaf-webber (Phycita sp.) were imported into quarantine in Brisbane. This report deals with the host specificity test results for these two agents.

Aims/objectives
The objectives were to:
1. import the leaf-webber (Phycita sp.) and scale insect (A. indicus) from India;
2. conduct host specificity tests with the two agents using over 80 test plant species; and
3. seek approval to release the agents in Australia if proven to be host specific.
Methods used
Standard no-choice and choice host specificity tests under quarantine conditions and a non-target risk assessment process have been followed for the two agents. The rearing methods for the two agents were standardised and no-choice host specificity tests on 26 test plant species for the leaf-webber and around 28 test plant species for the scale insect are either in progress or have been completed.

Results/key findings
Two biological control agents, a leaf-webbing caterpillar (Phycita sp. A) and a scale insect (A. indicus) were imported and rearing methods standardised. Cultures of both agents are being maintained in a quarantine facility at the Ecosciences Precinct, Brisbane.

Plants for host specificity testing have been sourced from nurseries (28 species) and grown from seed (30 species).

For the scale insect, no-choice nymphal survival and development tests have been completed on 14 species, and are underway for a further 14 species. The scale has completed development on three non-target plants, two of which are Australian natives. Further assessment examining the suitability of these two native non-target plants for sustaining populations of the scale is underway.

For the leaf-webbing caterpillar, no-choice larval survival and development tests have been completed for 16 test plant species and are nearing completion for a further 10 species. Larval feeding and development through to adults has occurred on 13 non-target Australian native plant species. Choice tests for adult oviposition and larval feeding preference are in progress.

In view of the potential non-target risk due to larval feeding and development by Phycita sp. A on some Australian native plant species, further screening of test plants with this agent will not be conducted. Instead, the potential to import a second species (Phycita sp. B) of leaf-webbing caterpillar that appears damaging in the native range in India will be evaluated.

Implications for relevant stakeholders
Successful biological control of prickly acacia will result in economic (increased pasture production, reduced mustering costs, enhanced stock movement, greater accessibility of water to stock, decreased bore-drain maintenance costs and reduced damage to tyres of farm vehicles), environmental (reduced soil erosion, water conservation, reduced reliance on herbicides and less displacement of native grasslands and associated fauna) and social (reduced weed seed spread, improved water-flow in channels and improved property values) benefits to the affected regions of Queensland, the Northern Territory and Western Australia.

Recommendations
If the host specificity test results suggest that these agents are adequately host specific and do not pose a risk to any non-target plants, then applications seeking approval to release them will be made to relevant regulatory authorities in Australia.

Communications

Research updates to Qld Rural Land Protection Council and prickly bush management group.


(PRJ-006877)
The weight of the vine: Impacts of vine infestations on plant health

Researcher/contact
Dr Kris French
University of Wollongong

What the report is about
This project identified the levels of infestation of vines, particularly Madeira vine and Cat’s claw creeper in rainforests along the East Coast of Australia. The project developed an easy way to measure the biomass of vines and investigated the impact of vines on native rainforest species both in the field and in the glasshouse.

Who is the report targeted at?
The information in this report will be of interest to scientists in weed ecology and land managers where vines have become a problem.

Where are the relevant industries located in Australia?
These vines have invaded rainforests in coastal Qld and northern NSW. These weeds have just been included as Weeds of National Significance (WoNS) at the national level but state governments will be largely involved in control in both states. The exotic vines have the potential to cause losses of Australia’s biodiversity, influencing conservation, aesthetic values as well as industries associated with our natural areas.

Background
Woody vines can cause significant damage to ecosystems. Exotic woody vines are common along edges of fragmented habitats and some species are particularly destructive and becoming increasingly common. Currently, in Australia the extent of invasion of Madeira vine (Anredera cordifolia) and cat’s claw creeper (Macfadyena ungui-cati) and the identification of species and plant communities most at risk is largely unknown. A lack of knowledge of the degree and type of damage will hamper appropriate management strategies.

Aims/objectives
The main objectives of this research were to:
1. undertake a survey of closed forests throughout the main distribution of Madeira vine and Cat’s claw creeper in NSW and Qld to identify which communities have been affected by these two species and other co-occurring exotic woody vines;
2. identify particular host species at risk from vine damage;
3. identify and measure levels of physical health of host plant species infested by woody vines;
4. compare biomass of exotic woody vines in the field through developing an easy biomass estimation method.

As new WoNS, our results will be able to feed directly into management plans for these species, providing an easy-to-measure estimate of vine growth at sites.
Results/key findings

Surveys

To date, 219 tree species have been recorded as being hosts of woody vines, with the potential for 50 more species to be identified as hosts from remaining samples. Madeira was found to infest 28 different species while Cat’s claw was found on 48 species.

Madeira vine was present in 13.3% of all plots surveyed. It was much more prevalent on forest edges than interiors, being found in 23% of all edge plots and only 4% of interior plots. In contrast, Cat’s claw showed less preference for edges, being present in 17.4% of interior sites and 27% of edge sites, and overall was found in 22.2% of sites visited. In at least two locations infestations of Cats Claw were observed encroaching into previously undisturbed interiors from forest edges, and was the primary form of disturbance in these plots.

On average, each plot showed at least two signs of vine-related host damage, ranging from broken branches to tree stems being split or girdled, to tree death. Trees infested with exotic lianas showed significantly more damage than those growing under native vines, with hosts of Madeira and Cat’s claw creeper having higher levels of host damage than the average scores per plot. Madeira hosts on the edges of forests were more damaged than those in interiors, whereas hosts of Cat’s claw showed similar levels of damage on edges and interiors.

Tree damage was more severe on forest edges, concurring with the observation that edges were significantly more disturbed than interiors. The more signs of disturbance in plots, the lower the native vine biomass, whereas exotic biomass showed a trend to increase with higher disturbance.

Vine Biomass

The relationship between stem diameter and above ground biomass was measured for 3 species of native and three species of exotic vine (including Madeira and Cats claw). The relationship did not differ amongst species suggesting that the canopy biomass of all vine species can be estimated from simple measures of stem diameter. Madeira vine and Cats claw creeper did not differ from native vine species in how much above-ground biomass it produced for stem diameter. This suggests that native vines that increase at disturbed sites may threaten rainforest structure.

In seedling competition experiments, a native host, Guioa semiglauca had significantly lower above ground (including stem mass), below ground and total biomass when grown with Madeira vine compared to when it was grown with the native Pandorea pandorana. Hosts competing with Madeira had similar leaf mass and biomass to another exotic vine tested, Araujia sericifera. In contrast, a native, Cissus antarctica, had the same effect on the biomass of hosts as Madeira vine. The effect of vine competition on above ground biomass was greater when plants were grown in higher light (30% of full sunlight) compared to 10% representative of under forest canopies. The lack of difference in effects of Madeira and Cissus suggest that vine growth strategy has an important effect on host biomass - both Madeira and Cissus have large leaves which may shade out hosts at the seedling level.

Interestingly, Madeira growth rates were higher when in competition than when it was growing alone or with another Madeira plant. Leaf mass was also higher when it was competing, but only when grown in higher light. In contrast, Moth vine was not impacted by light, and only had higher belowground biomass when competing with a host.

Implications for relevant stakeholders

As new WoNS, our results will be able to feed directly into management plans for these species, providing an easy-to-measure estimate of vine growth at sites. The information also provides a key link between host damage and vine infestation, particularly for Madeira vine, identifying clear indications of degradation of our native forests.

Recommendations

These results will be particularly important for the national coordinator who will be able to use this information in the development of a control and eradication plan. Providing results to land managers will help in assessing control priorities and the risks of future disturbances within national parks for rainforests.

Communications

Research results were discussed with DEEDI, OEH (NSW) and Kym Johnson. Communications had not yet been conducted. Planned outputs:

PLANNED PEER-REVIEWED PUBLICATIONS

- Predicting invasive and native liana biomass in rainforests?
  Biological invasions
- Above and below ground competition of vines on rainforest seedlings.
  Weed Research
- The link between vine invasion in rainforests and disturbance.
  Austral Ecology

PLANNED PRESENTATIONS

- Contribution to workshop run by national coordinator Kym Johnson in August outlining our results to policy and land managers.
- Spoken paper at the Ecological Society of Australia conference, Melbourne, Dec 2012
  (PRJ-006882)
Weed risk assessment for Australian nursery & garden industries

Researcher/contact
Dr Anthony Kachenko
Nursery & Garden Industry Australia

What the report is about
This report details work undertaken by the Nursery & Garden Industry Australia (NGIA) to develop a Weed Risk Assessment procedure (WRAP) for the Australian nursery and garden industry (NGI) based on the Botanic Gardens WRAP. The WRAP developed for the NGI was used to screen 1,000 cultivated ornamental taxa to determine the level of risk for each taxa based on the Köppen classification scheme that includes the following key climatic regions: equatorial, tropical, subtropical, desert, grassland and temperate regions.

Who is the report targeted at?
This report targets all sectors of the Australian NGI, primarily the production sector which supplies to a variety of markets such as retail, forestry and revegetation. The report is also targeted to these markets and the wider community who purchase taxa. The Botanic Gardens across Australia are also targeted by this report.

Where are the relevant industries located in Australia?
This project is applicable across Australia. Indeed, the Australian NGI is located in all jurisdictions across Australia, however much of the industry representation is along the eastern seaboard. The Australian NGI is one of the fastest growing sectors within horticulture and employs more than 45,000 people in over 20,000 small to medium sized businesses with a combined supply chain market value in excess of $6 billion annually. Markets supported by the nursery industry include Landcare groups, forestry, cut flower, fruit and vegetable growers, indoor plant hire enterprises and revegetation contractors. The production sector will benefit from this research as they will be able to screen taxa that they cultivate using the WRAP to ensure they are low risk. All markets that purchase plants will be able to make informed decisions when purchasing taxa that have been screened. Labelling manufacturers that portray the results of the WRAP for select taxa on labels may also benefit commercially over companies that fail to specify this information on plant labels.

This report targets all sectors of the Australian NGI, primarily the production sector which supplies to a variety of markets such as retail, forestry and revegetation.
Background
For several years, the Australian NGI has endeavoured to act responsibly in managing invasive plants through awareness campaigns and educational materials, including tools and resources for production and retail nurseries across Australia. The industry is aware that a whole of community response is required to address invasive plants at both a regional and national level requiring cooperation from all stakeholders including government, utilities and the broader community. This Invasive Plants Policy Position for the Australian NGI noted that industry was calling for “...a nationally agreed and adopted weed risk assessment process to be used at all levels...”. Through correspondence, the Australian NGI was provided with the summary paper on the Botanic Gardens WRAP (Virtue et al. 2008) and a brief overview of the process involved in the scoring of taxa. Through consultation with a variety of stakeholder, it was deemed that the Botanic Gardens WRAP could be adopted with minimal changes and applied to ornamental taxa cultivated by nurseries across Australia.

Aims/objectives
To develop a WRAP tool for the Australian NGI and engage businesses within the NGI as responsible community leaders on weed issues. The objective is to provide the wider Australian public with information and resources to assist them in making informed choices when purchasing plants. Production nurseries, retail garden centres, botanic gardens and the wider Australian public will benefit from this research.

Methods used
Stakeholders were consulted at the commencement of the project regarding what changes were required to the Botanic Gardens WRAP for use by the NGI. A consultant was then engaged to develop a desktop and web version of the Australian NGI WRAP and a consumer website. An experienced horticultural consultant was then engaged to complete 972 assessments using the Australian NGI WRAP. A review workshop was held wrapping up the project and to detail next steps. A consumer website and update to the NGI Plant labelling Guidelines is underway.

Results/key findings
The Australian NGI WRAP was successfully developed and tested with 972 commonly cultivated taxa. 48% of taxa were endemic. Of the 972 assessments, 80% of taxa were determined to be low risk. Only 0.1% of assessments were high risk. The project highlighted difficulties in assessing cultivars, hybrids and ‘sterile’ plant taxa as there was often little background information to adequately address the questions under the WRAP process. The project also identified that the Köppen classification scheme could be broken down into subregions to provide more localised results. The research will provide industry with a recognised mechanism to assess taxa for weed risk in the long term by incorporating this tool into industry ‘best management programs’ and national plant labelling guidelines. A consumer website will also be developed to ensure the wider community can benefit by making informed choices when purchasing taxa.

Implications for relevant stakeholders
Industry have a tool to assess taxa for weed risk to ensure only low risk taxa are cultivated and sold to communities across Australia. Communities will be able to make more informed plant purchasing decisions. Policy makers will be able to use the tool to develop a white list of taxa that are safe for cultivation, and trade in Australia.

Communities will be able to make more informed plant purchasing decisions. Policy makers will be able to use the tool to develop a white list of taxa that are safe for cultivation, and trade in Australia.

Recommendations
Ensure that all current and future taxa cultivated and sold in Australia are screened by the NGI WRAP. This is targeted to the Australian NGI with support of relevant stakeholders such as Botanic Gardens.

Communications

A press release developed by RIRDC and was used in the following:

An article on the project also appeared in ‘The Propagator Newsletter’ Summer 2011 No 32.

NGIA will be presenting the research at the 18th Australasian Weeds Conference in October 2012. Other publications will eventuate from this project pending project developments such as updates to the National Plant Labelling Guidelines.

(PRJ-006895)
Biological control of weeds in south eastern Australia

Where are the relevant industries located in Australia?
The five WoNS targeted by this research impact on agricultural production and environmental values across broad areas of south eastern Australia. This research will benefit farmers, Landcare groups, natural resource management agencies and public land managers responsible for the management of WoNS.

Background
The five weeds targeted in this project are (i) blackberry, (ii) gorse, (iii) Chilean needle grass, (iv) English broom and (v) Montpellier broom, which are listed as WoNS. All are either serious agricultural or environmental weeds, or both, and all have a major economic impact. Because of the difficulty and ever increasing expense of controlling these weeds by conventional methods, biological control offers a relatively cheap and effective tool to reduce weed vigour, seed output and rate of spread, that can be integrated into weed management programs. The practice of classical weed biological control is a public interest science as all landholders and public land managers in south eastern Australia with the weed species being controlled receive benefits, and those without the weed become less likely to be invaded by it.

Aims/objectives
Develop new biological control agents for the WoNS blackberry, gorse, Chilean needle grass, English (Scotch) broom and Montpellier (Cape) broom.

Methods used
Three insects were tested at DPI’s Frankston quarantine laboratory. (i) Choice oviposition tests of gorse pod moth *Cydia succedana* were completed to enable an application for field release in Australia, and (ii) host specificity testing of *Gonioctena olivacea* and *Agonopterix assimilella* was conducted for the biological control of English broom. At CSIRO’s Montpellier (France) laboratory, preliminary host specificity testing of *Lepidapion nr argentum* for the biological control of Montpellier (cape) broom was conducted using no-choice tests. A whole plant inoculation technique was developed for *Septocyta ruborum*, a potential biological control for blackberry. The field specificity of *S. ruborum* in New Zealand was assessed, and a global genetic phylogeny for the agent was submitted for publication. Host specificity testing of the Chilean needle grass pathogen *Uromyces pencanus* was completed in Argentina.
Results/key findings

It is unlikely that gorse pod moth *C. succedana* will attack commercial cultivars of lupins in Australia, and any risk that larvae could survive on commercial species/cultivars of lupins in numbers large enough to inflict significant damage is very low. The release of gorse pod moth for the biological control of gorse in Australia is recommended.

Host testing of the Chilean needle grass pathogen *U. peneinclus* showed some risk to two closely related Austrostipa species, however, the introduction of *U. peneinclus* to Australia is unlikely to cause any significant negative impact on native or otherwise valued plants or fungi, and its release is recommended.

No feeding damage from the English broom leaf beetle *Gonioctena oливacea* was observed on any of the Australian native species tested. Damage was restricted to the exotic and introduced tree legume *Chamaecytisus proliferus* and two species of *Lupinus* (*L. albus* and *L. angustifolius*). It is recommended that additional testing of broom leaf beetle should be conducted to identify the oviposition preference of females to confirm if these species could be at risk in the field of sustaining viable populations of the beetle.

The other potential English broom agent, the soft shoot moth *Agonopterix assimilalis*, requires further choice oviposition test and field surveys in New Zealand to determine whether females, under more natural conditions, would oviposit on Australian native species, and to assess the potential for this insect to shift to non-target plants.

Studies in France of the weevil *Lepidapion argentatum* have found that its potential as a biological control for Montpellier (Cape) broom may be better than previously thought. Not only can it develop in pods reducing the number of seeds, we now know it can also induce galls restricting the New Zealand population of *C. succedana* infestation levels in *Lupinus* spp. at Tikitere Forest, New Zealand. Unpublished Report, Scion, Rotorua, New Zealand.

Proposed publication: Adair, R. and Lawrie, A. Development of testing protocol and host specificity of purple blotch disease (*Septotxyra ruborum*) from blackberry.

**Recommendations**

Submit applications to release (i) *C. succedana* for the biological control of gorse, and (ii) *U. peneinclus* for the biological control of Chilean needle grass. Continue development of promising agents for blackberry, Montpellier broom, and English broom.

**Communications**


Ireson, J. 2012 Application to release the gorse pod moth, *Cydia succedana* (*Lepidoptera: Tortricidae*) for the biological control of gorse, *Ulex europaeus* L. (*Fabaceae*). Unpublished report for submission to AQIS, Department of Primary Industries, 100pp.


**Implications for relevant stakeholders**

Approval to release two new agents, one each for gorse and Chilean needle grass, would provide a new and important tool for the management of WoNS in Australia.
Management of glyphosate resistant weeds in non-agricultural areas

Researcher/contact
A/Prof Chris Preston
University of Adelaide

What the report is about
Herbicide resistance in non-agricultural situations is not reported often and little is known about the risks of herbicide resistance in these areas. This report outlines the findings of an investigation into the extent of glyphosate resistance present in non-agricultural areas across Australia, as well as identifying the information needs of users of glyphosate in non-agricultural areas.

Who is the report targeted at?
Users of glyphosate in non-agricultural areas including local councils, state RTA’s, railway and water authorities.

Where are the relevant industries located in Australia?
This project is relevant to all non-agricultural users of glyphosate and other herbicides across Australia. This includes local councils, state government instrumentalities, water infrastructure managers, businesses and farmers.

Background
Glyphosate is the most widely used herbicide for weed control in Australia and is the herbicide of choice for many situations, particularly those managed by state and local governments and instrumentalities. The intensive use of glyphosate for weed control has resulted in glyphosate resistant weeds evolving in situations including railway rights-of-way, roadsides and irrigation channels. Widespread resistance to glyphosate in these areas will have significant impacts on weed management in these sectors, as well as potential spread to other sectors. The evolution of glyphosate resistant weeds will increase the difficulty of weed management on roadsides, railway rights-of-way and irrigation channels. Alternative practices to glyphosate will have to be adopted to manage glyphosate resistance. There is a need to identify appropriate alternative practices, as well as to identify the information requirements for glyphosate users in order that appropriate information and strategies can be delivered.

Aims/objectives
To identify risks of glyphosate resistance evolving on land managed by local councils, railways, transport and water authorities in Australia and other users of glyphosate. To identify information requirements and strategies for all users of glyphosate that will reduce the risk of glyphosate resistance occurring and better manage the movement of glyphosate resistant weeds.
Methods used
Surveys were conducted across Western Australia, South Australia, Victoria, New South Wales and Queensland to collect weed species present on the roadsides, along railway right-of-ways and around buildings or irrigation channels. Four different weed species were targeted in the survey: annual ryegrass (Lolium rigidum), fleabane (Conyza bonariensis), windmill grass (Chloris truncata), and barnyard grass (Echinochloa colona). Collected plants or plants grown from collected seed were tested with appropriate rates of glyphosate to identify resistant individuals. A total of 122 plant species were assessed for herbicide resistance risk using DEEDI’s assessment protocol to identify species at risk of glyphosate resistance and sectors at risk in Queensland. Face-to-face and telephone interviews of at risk of glyphosate resistance and sectors at risk in Queensland. Glyphosate was the most widely used herbicide, followed by metsulfuron-methyl. The weed risk assessment arising from information provided identified 16% of the 122 weed species assessed as having high risk of glyphosate resistance. Sector risks identified water authorities as having the highest risk of developing glyphosate resistant weeds.

Results/key findings
More than 400 samples of whole plants or seed of the four species were collected from SA, NSW, QLD, VIC and WA. Resistance was identified in all four weed species. High frequencies of resistance were identified in annual ryegrass and fleabane where more than 50% of populations were found to contain high numbers of resistant individuals. Resistance was identified in all states surveyed. Glyphosate resistance was found to occur in all non-agricultural areas surveyed. A majority of resistant samples were from roadsides. However, resistance was also identified along irrigation channels, railway rights-of-way and around buildings, such as silos.

An electronic survey and eight workshops were used to identify weed species targeted and weed management practices in non-agricultural areas across three catchments in Queensland. Glyphosate was the most widely used herbicide, followed by metsulfuron-methyl. The weed risk assessment arising from information provided identified 16% of the 122 weed species assessed as having high risk of glyphosate resistance. Sector risks identified water authorities as having the highest risk of developing glyphosate resistant weeds.

Interviews with managers identified a wide range in the knowledge of herbicide resistance and management risks, from knowledgeable to completely unaware. Many constraints to the use of weed management practices other than glyphosate were identified including: budget constraints, environmental factors, training and understanding of alternatives.

Implications for relevant stakeholders
Non-agriculture sectors where glyphosate is used exclusively for weed management have a high risk of glyphosate resistant weeds evolving. These weeds will cause management difficulties for those sectors and may spread to other sectors. Weed management practices other than glyphosate need to be adopted to reduce this risk.

Recommendations
There is a need for accurate information on herbicide resistance risks and alternative management practices to be provided to weed managers in non-agricultural areas.

Communications


Report on alternative herbicides for weed management on roadsides and irrigation channels. To be published on AGSWG website.

Eight workshops conducted in Queensland.

(PRJ-006914)
Reducing the impact of tropical grassy weeds through effective risk management

Researcher/contact
Dr Samantha Setterfield
Charles Darwin University

What the report is about
This report describes research on the development of a systematic framework for allocating weed management effort to effectively control grassy weeds. The framework can be used to assess current management efforts and threats to environmental and cultural assets from future invasion as well as allocate funding to minimize loss of assets.

Who is the report targeted at?
This report is targeted at decision makers allocating resources to gamba grass (*Andropogon gayanus* Kunth.) management, ranging from local landholders undertaking strategic weed management planning for their property to government agencies allocating financial resources to regional weed management programs.

Where are the relevant industries located in Australia?
The largest infestations of gamba grass are located in the Northern Territory (estimated 1-1.5 million hectares of infestation in NT). Significant areas of invasion also occur in Queensland. Therefore, the relevant industries for this report are those organizations tasked with on-ground control of gamba grass (including local landholders and contractors) to government branches tasked with allocating resources to weed management such as the NT Weeds Branch and Territory NRM.

Background
The social, economic and environmental impacts of invasive plants are well recognized. However, the social and economic costs of managing and eradicating invasive plants are rarely accounted for in the spatial prioritization of funding for weed management. Gamba grass is a Weed of National Significance and one of five species of tropical invasive grasses that have been listed as a Key Threatening Process (KTP). This project was undertaken to address the very urgent need for a prioritization framework that land managers could use to identify optimal allocations of their weed management budget to both eradication and control measures of gamba grass. The framework would be applied to minimize the costs (including management costs as well as loss of social, cultural and environmental assets) and likelihood of reinvasion. The developed framework extends recent approaches to systematic prioritization of weed management to account for spatially variable environmental, social and cultural assets that are threatened by gamba grass.

“Isolated control and eradication efforts for gamba grass are likely to be threatened by the expansive spread from infestations not immediately managed to prevent spread.”
Aims/objectives
The objective of the project is to develop a decision support framework for the management of tropical invasive grasses based on systematic conservation planning approaches. This research benefits decision makers allocating limited funding to maximize their impact on managing gamba grass. The aim is to provide decision makers with a framework for explicitly considering competing objectives for weed management including minimizing future spread and recovering currently infested assets. This framework was applied to the northwest region of the Daly because of its high natural and cultural values and large gamba grass infestations, but it may be applied at the local property level up to broad regional planning.

Methods used
A general framework was firstly developed that accounts for spatially variable environmental, social and cultural assets that are threatened by gamba grass. Then a simulation model was developed using the general framework using the current distribution and density of gamba grass, modelled predicted patterns of spread, modelled cost of eradication, modelled cost of control measures, and finally mapped assets, to allocate funding to management through time. Several budget scenarios were considered in order to estimate the benefit of immediate management of gamba grass compared to delayed or limited action.

Results/key findings
The key result of this project was a draft framework for allocating weed management effort to effectively control weeds. The framework extends recent systematic approaches to weed management by considering the spatial distribution of key assets including biodiversity and cultural sites of significance. Importantly, the framework uses a multi-year scheduling approach to allocating resources to management across time and space. The framework uses a cross-disciplinary and integrated approach using linked economic and biophysical models. In addition, the framework builds on collaborations with stakeholders and government departments to ensure all known infestations were mapped and included in the data sets and key assets were identified and mapped as well as considering existing management efforts. Key findings from the project include financial estimates for control and eradication of gamba grass. For all mapped infestations in the study region (~18,000 ha), an annual budget of $1,600,000 is needed to control gamba grass. In comparison, a budget of $20,000,000 is needed over 10 years to eradicate all mapped infestations in the region. The first year cost of an eradication program is four times greater than control; however, when comparing the present value of a control program in perpetuity to a 10 year eradication program, the control program is ~2.5 times greater ($52 million net present value for control compared to $19 million for eradication assuming a discount rate of 3%). Another key finding from the project is, given the rapid spread of gamba grass, if management efforts are undertaken in isolation, spread from neighbouring properties will re-infest cleaned sites. Therefore, emerging trends from the study region include the importance of controlling along property boundaries to reduce infestation into neighbouring properties, putting in place containment borders to reduce expansive spread and loss of assets, and considering when to switch between eradication and control activities once control is established across the region.

Implications for relevant stakeholders
Isolated control and eradication efforts for gamba grass are likely to be threatened by the expansive spread from infestations not immediately managed to prevent spread. Therefore, it is critical for funding bodies to understand how control initiatives may or may not result in outcomes based on strategic location of these projects such that they are not threatened from re-invasion. The framework allows organizations to assess the contribution of individual control measures to broader regional weed management goals.

Recommendations
Due to expansive spread rates of gamba grass, immediate control of known infestations is needed to prevent future loss of assets. If small infestations are not immediately controlled spread from these sites will threaten the success of control and eradication at prioritized sites.

Communications
PRESENTATIONS
Spatial prioritization for management of Andropogon gayanus (Gamba grass) invasions, 18th Australasian Weeds Conference, Melbourne, October 2012.

PLANNED PUBLICATIONS
Spatial prioritization for management of Andropogon gayanus (Gamba grass) invasions, conference proceedings Australasian Weeds Conference (submission attached).

Allocating scarce resources to control of highly invasive weeds: when and where to act, Conservation Biology.

Adding fuel to the fire: the financial risks of Andropogon gayanus to savannah burning carbon abatement projects in northern Australia, Environmental Research Letters.

(PRJ-006928)
Biological control of Weedy Sporobolus Grasses (WSGs) by the fungus Nigrospora oryzae

Background
Previous research has shown the local fungus N. oryzae produces crown rot that can kill giant Parramatta grass (GPG) and reduce infestations to non-economic levels over a couple of years. Preliminary host specificity research showed N. oryzae disease was confined only to GPG. Research into the deliberate introduction of N. oryzae in GPG infestations is needed.

Beneficiaries of project
The industry most likely to benefit from this research is the beef industry. Australia has an estimated 59,000 beef producers and 26.2 million head (ABS). Around 45% of Australian cattle are in regions known to have WSGs on a % basis, meaning 26,600 beef producers are potentially impacted. In 2007, 450,000 ha of coastal grazing land across the East Coast were estimated to have WSGs. At that time loss in production costs were estimated at $60 million in an industry valued at $8.1 billion in 2010/11. Some WSG affected producers are known to take an extra 12 months to get to cattle to equivalent market weights as those on WSG free land. WSGs are responsible for reducing culling age of cows and also impacting on property values particularly in QLD. The main markets affected by WSGs are the production of weaners on the NSW north coast, animals destined for both domestic and export beef markets from eastern QLD. This project will potentially benefit all producers with WSGs.

Objectives
A host specificity assessment of N. oryzae against selected pasture and crop species is to be completed. The initial value of artificial inoculation with N. oryzae in the field is determined. The progress of disease in natural field inoculations continues to be monitored. Preliminary research into N. oryzae for the potential for commercial laboratory spore culture has commenced. The final aspect of this project is to seek to develop means of inoculating and inducing disease in other WSGs.

Methods used
We conducted glasshouse research into the susceptibility to N. oryzae of some weedy and native Sporobolus species along with selected pasture and crop plants. Field experiments examined the efficacy of N. oryzae spore solutions and diseased GPG plants as means of artificially inducing disease. Preliminary field and glasshouse research in the concentration of spores needed to induce disease and management of plants prior to inoculation has begun for GPG and to a lesser extent GRT. Laboratory research has included a survey of types of fungi found on WSGs in the field. Also, initial experiments into the culture conditions required for commercial spore culture and the potential role of other fungi in inducing disease has commenced.

Researcher/contact
Mr David Officer
NSW Department of Primary Industries

What the report is about
Control of WSGs is currently dependent on chemicals which are expensive, have long a payback period and often provide short term suppression. Biological control of WSGs is needed and is now a viable option for NSW north coast producers. This project describes the initial months of field experiments evaluating a local biocontrol agent N. oryzae. It also shows the first evidence of N. oryzae inducing disease in Parramatta grass (PG: S. africanus) and giant rats tail grass (GRT: S. pyramidalis). Results of N. oryzae host specificity research and preliminary experiments into the commercial production of spores are presented.

Who is the report targeted at?
This report provides information for researchers and weed controllers interested in controlling WSGs and primary producers looking to control WSGs in cost effective, chemical free and sustainable ways.

Where are the relevant industries located in Australia?
This research is most widely known and strongly supported in coastal northern NSW but we have received enquiries ranging from North Queensland to the NSW south coast. There is untapped potential for significant interest in this research from producers affected by S. africanus throughout Victoria.
Results/key findings

Both planting diseased GPG and inoculation with N. oryzae spores has proved initially effective in the field.

Solid culture of N. oryzae works but commercialisation will need further development as liquid culture of spores has so far proved unreliable.

N. oryzae is now known to induce disease in two other WSGs, S. africanus and S. pyramidalis. Both these species have been found with crown rot disease in the field. A survey showed N. oryzae diseased GRT plants as far north as central QLD. The southern boundary of known diseased GPG is now the lower NSW mid north coast. Disease symptoms have now also been found in the native S. virginicus but not two other Sporobolus natives.

Implications for relevant stakeholders

Northern NSW coastal producers are already starting to utilise N. oryzae as a control measure for GPG and GRT by moving diseased GPG plants onto their properties when they can locate suitable material. Some of the experimental field sites will be able to be used as sources of diseased plant material as of spring 2012. Local weeds officers are being encouraged to identify additional sites of diseased GPG to assist in the spread of N. oryzae.

There are currently restrictions on the movement of WSG plants across state borders. Therefore, it is important for each state to identify and utilise any existing local infection sites. Alternatively, funding will be needed to continue to develop commercially viable spore production techniques.

Recommendations

This report presents the first 6 months of field experiments with artificial N. oryzae inoculations. These experiments need ongoing monitoring for at least 18 months past this projects completion date. Funds for ongoing monitoring, additional field and spore production research are needed and still yet to be identified.

Communications

This project’s potential and actual results have been presented to producers and weed professionals from North QLD to southern coastal NSW at producer weed forums, the 2011 QLD Weed Society symposium and regional weed meetings. The intent is produce a WSG biocontrol brochure and to present limited data at the 2012 Australian Weed Society conference.

See table below.

(PRJ-006932)
Use of hyperspectral remote sensing for enhanced detection of weeds

Researcher/contact
Dr Remy de Haan
Charles Sturt University

What the report is about
This research is about the development of an unmanned hyperspectral remote sensing platform capable of collecting high spatial and spectral resolution information about weed abundance and distribution at both the farm and catchment scale. Management implications include improved profitability and sustainability in agricultural and environmental systems through the use of targeted weed management.

Who is the report targeted at?
The report is targeted at a “learning community” of weed researchers, spatial modelers and image analysts who will work with community and catchment groups, crop and landscape weed consultants, producers and land managers to test, validate and develop the use of an Unmanned Aerial Vehicle (UAV) for multi-purpose weed detection and distribution mapping on a landscape scale.

Where are the relevant industries located in Australia?
The “learning community” could exist anywhere in Australia where weed management is problematic. Areas such as crop and water catchments, forests, rangelands, pastures and mountainous regions harbor invasive weeds. These areas could yield important data regarding weed infestation, movement of invasive weed fronts over time and success of management strategies after implementation.

Background
The underlying theme of this project was to develop an Unmanned Aerial Vehicle (UAV) integrated with a hyperspectral remote sensing system capable of high spatial resolution. Management implications include improved profitability and sustainability in agricultural and environmental systems through the use of targeted weed management. To achieve this it was necessary to integrate a suitable unmanned aircraft capable of carrying payloads greater than 5kg, with an aircraft control and communication systems capable of stable unmanned flight and onboard sensors capable of recording high frequency positional and aircraft altitude information during flight.
Aims/objectives
To develop a model system for the extraction of spectral information from hyperspectral imagery to produce semi-quantitative abundance maps of key invasive weed species in southern and eastern Australia. Moreover, to determine optimal spatial scale to cost-effectively map key weeds using hyperspectral imagery, the most appropriate spectral bands to use and the most efficient image analysis techniques to accurately map selected weed species across Southern Australia.

Results/key findings
To achieve the high spatial resolution (<10cm) required for detection in cropping canopies a platform was required that was capable of both lifting a large payload and moving extremely slowly (< 2m/s). Two UAV platforms were designed for evaluation, the first a helicopter for slow flight and the second a fixed-wing aircraft for more broad scale surveys. At test sites over twenty weeds were measured and the results were compiled as a digital reflectance spectral library of the weed spectra that cover wavelengths from the near-infrared to the shortwave infrared from 400 to 2500nm. The test sites were also used to determine the stability of the platform to ensure the flight control system functioned correctly, and to test the integration between the autopilot, data acquisition system and hyperspectral camera system.

Implications for relevant stakeholders
This project has built two unique UAV platforms and a hyperspectral imaging system that will allow a range of ongoing research applications linked directly to the goals of the National Weeds and Productivity Research Program. The system has been developed to address broader research questions including, calibration, potential for low cost end user platforms, and comparisons between multispectral, hyperspectral and optical sensing systems. Some of the future weed research questions include:

- What is the smallest patch of weeds that can be mapped using this technology and does the patch size and/or canopy architecture play a significant role in the detection of different weeds?
- What effect does pixel size or scale have on the detection of different weed species?
- What level of accuracy is acceptable for management of target weeds species?
- What weeds can and cannot be detected remotely?

Recommendations
The UAV control equipment and UAV's can be assembled and ready to fly within an hour of arriving at a test site. To operate the UAV system requires a minimum of three people. The Chief Controller is in charge of all operations and safety. Two people are required for flight operations and safety while a third is required for computing and communications. It is envisaged that in practical end user applications where only line-of-sight flights are required and as autopilot systems evolve, the flight crew might be reduced to a single person for small UAV’s. Plans exist to continue our work with weed researchers, spatial modelers and image analysts who collaborate with community and catchment groups, crop and landscape weed consultants, producers and land managers to test, validate and develop the use of UAVs and hyperspectral imaging system for multi-purpose weed detection and distribution mapping on a landscape scale.

Communications
Publications include a conference paper giving an overview of the system and outlining the preliminary mapping results to be delivered at the 18th Australasian Weeds Conference 8 – 11 October 2012; a review article (in preparation) on hyperspectral remote sensing for weed mapping for submittal to the Journal of Remote Sensing; and a paper describing the initial system and mapping performance of the UAV and hyperspectral system for the International Journal of Remote Sensing.

Plans exist to publish the spectral characteristics of weeds along with a series of case studies describing hyperspectral technology and its application in agriculture and resource monitoring.

Media releases included project potential for weed management using new technologies.


Two articles were also published in Autumn 2011 and 2012 releases of the EH Graham Centre for Agricultural Innovation quarterly newsletter the Innovator.

The UAV plane formed the lead in photo for the 2012 Autumn Innovator. The Innovator newsletter is designed to keep stakeholders informed www.csu.edu.au/research/grahamcentre/news/newsletter.htm.

A sequence of videos has also captured trial flights and will be released for publication.

(PRJ-006948)
A unified approach to evaluate fitness costs in herbicide resistant *Lolium rigidum*

**Researcher/contact**
Prof Stephen Powles
University of Western Australia

**What the report is about**
This research focused on the quantification of herbicide resistance fitness costs associated with various ACCase resistance mutations in *Lolium rigidum*.

**Who is the report targeted at?**
The results of the present investigation are of interest to professionals from both academic (ecologists, plant biologists) and agricultural (agronomists, farmers, extensionists) sectors.

**Where are the relevant industries located in Australia?**
*Lolium rigidum* is the major weed species in Australian agriculture. In addition, this species has been shown to evolve herbicide resistance to many herbicides. The results from the present investigation will benefit those actors involved in herbicide resistance management.

**Background**
A fitness cost associated with herbicide resistance is defined by a plant “handicap” or impairment of a plant function that compromises one or more components of plant fitness (e.g. growth rate) leading to alter the population dynamics of the herbicide resistant species (e.g. population frequency of resistance alleles over time). From an evolutionary perspective a plant fitness cost is seen as an “adaptation cost” to environmental changes. And within the context of herbicide resistance evolution, plants carrying evolved herbicide resistance genes are expected to express an ecological disadvantage when compared to plants carrying no resistance genes.

**Aims/objectives**
1. Evaluate the expression of fitness costs associated with various target site herbicide resistance ACCase mutations in *Lolium rigidum*;
2. Correlate the magnitude of fitness costs and the frequency of resistance genes in the field;
3. Identify weed management strategies to exploit those plant traits that lead to the expression of fitness costs.
Methods used
The different methodological protocols used make our research very novel and unique and the obtained results help understand better the evolution of ACCase herbicide resistance in L. rigidum from WA cropping systems. Expression of fitness costs were assessed in (1) isolated plants, (2) under competition with wheat, both (1, 2) in absence of herbicide selection. Our experiments were also designed to quantify the expression of fitness costs under the selection pressure imposed by a herbicide (clethodim). Seed germination studies were conducted to understand seed responses to a light environment. In our experiments at the plant level, three ACCase herbicide resistance homozygous mutations were studied ((1) Ile-1781-Leu, (2) Asp-2078-Gly and (3) Cys-2088-Arg) and compared to a set of four L. rigidum population known as ACCase herbicide susceptible and exhibit no ACCase herbicide resistance mutations.

Results/key findings
1. Fitness costs are associated with some but not all ACCase herbicide resistance mutations in L. rigidum;
2. Fitness costs may express in plants under no competition, under competition from wheat or under herbicide (clethodim) selection pressure;
3. Considering all the potential ecological environments evaluated in this project, a ranking of fitness costs from high, intermediate or low may be associated with plants carrying the Asp-2078-Gly, Cys-2088-Arg and Ile-1781-Leu, respectively;
4. The preceding fitness cost rankings correlates well with the frequency of the mentioned ACCase herbicide resistance mutations in WA cropping fields;
5. Agronomic practices such as use of highly competitive wheat cultivars, high seeding rates, and shallow seed burial and efficient herbicides can exploit the presence of fitness costs and thus, minimize the rate of herbicide resistance evolution in L. rigidum.

Implications for relevant stakeholders for
This study has provided insights into fundamental knowledge on herbicide resistance evolution in weeds. We anticipate that this research has yielded results at the forefront of research in the field, and that will have a significant impact in Australian agricultural sector.

Recommendations
Potential agronomic practices to manage herbicide resistance may contemplate the findings of this investigation and adopt the mentioned practices to minimize the evolution of herbicide resistance in Lolium rigidum.

Communications
There are currently two manuscripts (in progress) derived from this research project intended to be published in prestigious peer-reviewed international scientific journals:

Martin Vila-Aiub and Stephen B. Powles. The ecology and evolution of plant resistance to herbicides: the role of plant fitness on herbicide selection pressure (for submission to Proceedings of the National Academy of Science).


In addition, results from this investigation will be presented in the “Global Herbicide Resistance Challenge”, an international Conference to be held in Perth, on February 18-22, 2013.

http://www.herbicideresistanceconference.com.au
(PRJ-007096)
Improving prevention and containment of serrated tussock in SW Victoria

What the report is about
Serrated tussock is a highly invasive weed that reduces the productive capacity and threatens the biodiversity of the land. In Victoria, a community-led approach to serrated tussock management has been coordinated by the Victorian Serrated Tussock Working Party (VSTWP) since 1995. This report draws on a case study in south west Victoria to examine the challenges for serrated tussock management in a region that has an established infestation and where containment to that region is required for the prevention in neighbouring regions. It examines the networks of the stakeholders who are critical to the community-led approach and considers ways to make contact with those community members least likely to be engaged in serrated tussock management.

Who is the report targeted at?
The report aims to inform organisations who manage serrated tussock in the case study area, in particular those organisations involved in the coordination of landscape scale management. More broadly, the report will be of interest to organisations involved in the management of established, highly invasive weeds in a peri-urban environment.

Where are the relevant industries located in Australia?
Relevant agricultural industries in the affected or vulnerable areas are cropping and grazing. Infestations of serrated tussock are found in Victoria, to the west of Melbourne, in the Corangamite and Port Phillip and Westernport catchments with satellite infestations in the West Gippsland catchment. In NSW, infestations exist in the Central and Southern Tablelands and the Northern Tablelands. The weed is also established in south eastern Tasmania and on King Island in Bass Strait.

Background
In recent years, changes in government policy and the community have created new challenges for the community-led approach to serrated tussock management. In the core infestation area, there have been significant changes to land use and tenure. Landowners have become more heterogeneous and encompass a range of opinions and differing levels of commitment to weeds management.

In addition to the changing demographic of the region, the approach to managing invasive plants across Victoria has altered considerably since the introduction of the Biosecurity Strategy (DPI 2009). Priority is now given to preventing the spread of serrated tussock outside the core area whereas before it also sought to reduce the density of existing infestations. Some stakeholders believe that this move to containment has disengaged community members within the core areas.
**Aims/objectives**

The objectives of this study are to improve the likelihood of effective integrated weed management strategies that seek to contain a highly invasive weed to a core area. Specifically, it considers the best collaborative management and governance of preventing and mitigating the further spread of an established weed where there is only one option for a successful outcome and that is full adoption that involves all landholders in prevention and containment activities.

**Methods used**

A range of data collection methods were used including: a review of documents and the literature, semi-structured interviews, and a focus group. Semi-structured interviews were undertaken with two groups of stakeholders—staff of organisations and individuals who work on the land. Data from these interviews were also used to build and analyse the network with which these stakeholders were involved. Data from the two groups were analysed separately with initial findings then compared to the data from the literature review.

**Results/key findings**

Barriers preventing a collaborative and comprehensive approach to serrated tussock management: Government investment in serrated tussock management is directed towards containment rather than reducing the density of the core infestation. The containment approach is proving difficult to accept for some landowners who deal with the core infestation. This is because they see a decrease in enforcement by government and financial support for their community groups to carry out activities such as education and raising awareness. In addition, in the infestation area there is a changing demographic with an increasing turnover of properties and greater numbers of absentee and part-time landowners to the extent that resident community groups have difficulty connecting with many landowners.

Land manager relationships: Landowners with a history of farming have maintained strong and influential relationships with DPI. However, for a growing number of new landowners, this relationship has little influence when they have no interest in agriculture. In such cases, they are likely to have stronger relationships with the local council or the Department of Sustainability and Environment (DSE), especially when biodiversity and conservation are important to them.

Appropriateness of the community-led approach: This approach relies on partnerships between community, government, and other key stakeholders (including private landowners). Currently an agricultural bias exists among the organisational partners with local councils and community groups such as Landcare being under-represented.

Effective serrated tussock management: A long-term containment program requires a high degree of community support (DPI 2010). To achieve this in the peri-urban environment of core infestation requires the support of a consistent government enforcement program and funding available to community groups to reach an increasingly heterogeneous community.

A landscape scale approach: Serrated tussock can be more efficiently managed at a landscape scale. Management at this level needs partners who can represent the issue both geographically and in terms of the increasingly diverse land uses in the core infestation. As such, they should reflect the changing agricultural, conservation and other land uses of the region.

“This study has shown that a community-led approach to containment has particular challenges in a peri-urban environment. Landowners have different levels of commitment to their properties which affect their willingness to invest the time and resources needed for serrated tussock management.”

**Implications for relevant stakeholders**

This study has shown that a community-led approach to containment has particular challenges in a peri-urban environment. Landowners have different levels of commitment to their properties which affect their willingness to invest the time and resources needed for serrated tussock management. As a result, a range of tools is required to ensure that they meet their obligations as landowners.

**Recommendations**

Efforts should be made to increase partnerships with local councils and community groups to utilise their existing connections and influence with many private landowners. Greater effort is required by government to reach new and recalcitrant landholders, including a consistent and visible enforcement program and funding for community groups to carry out activities in education and raising awareness.

Increased focus should be given to include biodiversity and conservation outcomes when addressing established weeds that have a reduced focus under the State Government’s approach to biosecurity.

**Communications**

Findings from this study are to be presented to the Victorian Serrated Tussock Working Party quarterly meeting.

(PRJ-007114)
Does the tolerance of weeds to herbicide change with elevated CO2?

Researcher/contact
Dr Paul Downey
University of Canberra

What the report is about
There are over 3000 weed species in Australia, many of which pose significant threats to biodiversity, primary industries, and human health. Herbicide is the most widely used and effective method to control weed species, thus any decrease in herbicide efficiency could have potentially significant consequences for weed management. Given the responses of plants to increased levels of carbon dioxide, weeds may be more tolerant of herbicide with the advent of climate change. This report examined the effectiveness of herbicides on 20 weed species grown under elevated carbon dioxide.

Who is the report targeted at?
This report is targeted at weed managers especially those who use herbicide as a means of managing their weed problems.

Where are the relevant industries located in Australia?
The results of this project are most applicable to south eastern Australia, although they are relevant where the 20 weed species grow, including other countries. The results are mostly directed at weeds that invade natural ecosystems although some weed species are also problems in agriculture. The results will benefit many weed managers as it highlights the need for better monitoring and the potential for decreased herbicide efficiency in some species under future climates.

Background
Whilst the current and predicted future level of atmospheric carbon dioxide (CO2) has contributed significantly to the problem of global climate change, CO2 is important for plants, specifically during the process of photosynthesis. Many of the ways in which plants respond to elevated levels of CO2 may affect herbicide efficiency either through altered uptake rates of the active ingredient or by increased biomass which enables plants to better withstand the effect of the herbicide. Several studies have investigated the tolerance of a select number of weed species grown under elevated CO2 to herbicide, which showed that six of the eight species examined exhibited higher tolerances to herbicide when grown under elevated CO2 conditions (Ziska et al. 1999; Ziska & Teasdale 2000; Ziska et al. 2004; Manea et al. 2011). Given the small percentage of weeds examined, future investigation is needed to determine the broader trend.
Aims/objectives
The aim of this research is to determine if there is a broader trend of increased tolerance of weeds to herbicide when grown under elevated or future levels of CO2. This research is critical for all weed managers as herbicides are the main control technique used to control weeds.

Methods used
This project used a range of different methods to assess changes in herbicide tolerance to 20 weed species. The 20 weed species span a wide range of growth forms (eg grasses, herbs, shrubs and vines). Each weed species was grown under ambient (350ppm) and elevated levels of CO2 (550-650ppm). The survival rates of all weeds to herbicide application were assessed using a range of methods. Measurements of herbicide effectiveness included: visual assessments, direct morphological measurements, biomass assessments, and leaf function/health for some species (Leaf Chlorophyll, Photochemical Reactive Index (PRI), Stomatal Conductance, and the analysis of Digital Photos using leaf area software). Assessments of 20 weed species have been made to date.

Results/key findings
Results show that when a broader group of weed species is examined there is no consistent response that weeds grown under elevated CO2 are more tolerant to herbicide. Of the 20 weed species examined to date, two showed an increased tolerance to herbicide in terms of mortality when grown under elevated CO2 (Pennisetum clandestinum, Sonchus sp.). Two showed a decreased tolerance to herbicide in terms of mortality when grown under elevated CO2 (Solanum nigrum, Ageratina adenphora). Of the 20 weed species examined to date five showed increased function/growth following herbicide when grown under elevated CO2 (Chloris gayana, Hirschfeldia incana, Pennisetum clandestinum, Solanum nigrum, Sonchus sp.), although this increased function did not translate into lower levels of mortality. The results for the remaining species are inconclusive.

Increased rates of herbicide (i.e. double the recommended rate) did not appear to greatly alter the tolerance levels observed, which suggests that the management response to future changes in tolerance due to increased carbon dioxide is not simply greater volumes of herbicide.

This research will benefit weed managers in two main ways. It will raise the broad issue that some weed species will be more tolerant of herbicide under future levels of CO2. In addition, it will highlight some of the likely changes with examples based on the 20 weed species examined here.

Implications for relevant stakeholders
Whilst there was no consistent trend in the analysis, these results have broad implications for weed managers in that some species are likely to exhibit greater herbicide tolerance under future carbon dioxide levels.

There are some implications for herbicide companies in that they may need to look at ways to increase efficiency in the herbicides used for those weeds that exhibited greater tolerance under elevated CO2.

“...these results have broad implications for weed managers in that some species are likely to exhibit greater herbicide tolerance under future carbon dioxide levels.

There are some implications for herbicide companies in that they may need to look at ways to increase efficiency in the herbicides used for those weeds that exhibited greater tolerance under elevated CO2.”

Recommendations
Given the large number of weed species and the small number examined here, it is critical that weed managers adopt greater monitoring of their herbicide applications to help them assess any likely changes in herbicide tolerance.

Those species that show higher tolerance under elevated carbon dioxide need future research to improve the efficiency of the herbicides used. Although the results suggest that herbicide application under elevated CO2 conditions for most species delays mortality rather than prevents it.

Communications
This work was presented at the 11th EMAPI (Ecology and Management of Alien Plant Invasions) Conference in Szombathely, Hungary in September 2011 as a poster. In addition it has been accepted as a poster at the upcoming 18th Australasian Weeds Conference in Melbourne in October 2012.

(PRJ-007118)
Improving regional adoption of weed control

Researcher/contact
Prof Brian Sindel
University of New England

What the report is about
This research explored the impediments to adoption of weed control practices amongst private and public land managers, and the potential of collective action programs to overcome these impediments. A case study approach was adopted, involving serrated tussock control in two contrasting grazing regions of NSW, the Northern Tablelands and the Southern Tablelands.

Who is the report targeted at?
The research will be of most interest to policy makers and organisations involved in designing and implementing community-based programs to improve weed control adoption.

Community-based approaches offer a valuable opportunity to improve the uptake of effective weed management practices.

Where are the relevant industries located in Australia?
Serrated tussock (Nassella trichotoma) is currently found in the Northern, Central and Southern Tablelands of NSW, as well as in the ACT, central Victoria, and parts of Tasmania. It is of most significance to grazing operations but can also impact negatively on crop production. Primary producers in these regions, as well as public land managers, will most directly benefit from this research. However, the findings are equally applicable to collective management of other weed species.

Background
While reasonable scientific approaches to weed control have been developed for many weeds and land-use types, adoption of weed control is still often poor. One landholder will control weeds, while their neighbour will not. The lack of collective action has spillover effects on the environment, community and agricultural production in the surrounding region. Adoption barriers and incentives are often dependent on land manager needs, awareness and goals. For example, the weed management goals of commercial graziers, lifestyle farmers and public land managers will vary significantly. Any solution should therefore involve collective action, where individuals can trust that a critical mass of their neighbours will be adopting weed control just as they are. Community-based approaches may be useful here in helping to foster this trust by strengthening supportive social norms and informal monitoring and sanctioning.
Aims/objectives
The research sought to identify the barriers and incentives to adoption of serrated tussock control in each region. These included scientific/technological, knowledge, social/community, environmental, legal/institutional and economic barriers and incentives. The research explored ways in which barriers to adoption may be overcome, with a particular focus on facilitating collective action at a district level.

Methods used
The research was completed in three stages. First, Australian and international literature was reviewed to explore weed control adoption issues at a regional level. Second, a telephone survey was conducted of 100 rural landholders in each case study region. The survey explored the various barriers and incentives to control serrated tussock, and the viability of a community-based collective action program to improve control adoption rates amongst various landholder ‘types’. Third, workshops were held in each region to discuss the findings of the literature review and survey with landholders, weed experts and government agency staff, to refine future approaches to the problem.

Results/key findings
Significant barriers to serrated tussock control included poor management on neighbouring properties, lack of resources to control the weed effectively, a sense of apathy and futility regarding effective management prospects, and difficulty identifying the weed. Important incentives to improve serrated tussock management included controlling new outbreaks early, and ensuring the economic viability of the property. A range of barriers and incentives were identified specific to commercial farm managers, absentee and lifestyle farm managers, public land managers, and staff of relevant government and NRM agencies.

Improving adoption of serrated tussock control requires preferred modes of learning, differing property management goals, and relevant strategies to be taken into account. New farming residents in rural communities, particularly on smaller landholdings, need to be educated on their weed control responsibilities beginning at the time of sale. Sufficient information on serrated tussock management exists, but this information does not appear to reach all land managers. Many research participants were strongly in favour of stricter enforcement requiring both private and public land managers to control serrated tussock sooner, to backstop educational and incentive approaches. Weed control authorities were highly regarded, but considered to lack the resources to fulfil their role to full effect.

An effective community-based serrated tussock control program must involve trust and willingness to reciprocate on weed control behaviour. Several successful community-based land management programs were identified. Their success was based on strong participant interest in program outcomes, converging land management interests, achievable goals, financial or environmental motivation to take part, and external management and/or funding. These networks and cooperative models offer useful lessons for a serrated tussock program.

Implications for relevant stakeholders
Community-based approaches offer a valuable opportunity to improve the uptake of effective weed management practices. Encouraging private and public land managers to build relationships and work together on weed control will improve the capacity of those who are already motivated to manage weeds on their land, and motivate some individuals who have otherwise been apathetic about weeds. Improving adoption rates for weed control across rural landscapes will benefit all land managers.

An effective community-based serrated tussock control program will be based on strong participant interest in program outcomes, converging land management interests, achievable goals, financial or environmental motivation to take part, and external management and/or funding.

Recommendations
Further work is recommended to trial community-based management programs for weeds such as serrated tussock, and to apply the successful features of collective action land management programs already in operation. Existing community-based networks, and their applicability to weed management, need to be identified and utilised where possible to ensure program outcomes are ongoing. Different community-engagement models should also be explored for their relevance to different regions in Australia, as well as different weed species.

Communications

Two peer-reviewed publications planned with relevant Australian agricultural journals.

(PRJ-007151)
Weed management using fibres from agricultural wastes

Researcher/contact
Dr Menghe Malcolm Miao
CSIRO

What the report is about
The research assesses the feasibility of manufacturing a biodegradable weed mat (Eco Weed Mat) from agricultural waste as an alternative to a synthetic, nonbiodegradable product. The report also outlines the potential of a new fibre value-chain (similar to that in Canada) in Australia.

Who is the report targeted at?
The main audience is horticultural and broad acre growers who use weed mat, land managers in rural and regional Australia, managers of environmental assets, natural resource facilitators, and peri-urban land managers. The report is also relevant to growers of fibrous crops and manufacturers interested in new product lines.

Where are the relevant industries located in Australia?
The most likely users are broad acre horticulture, commercial gardens and parks, as well as home gardens, across Australia. The most prospective fibre source is from waste linseed straw in the Victorian, NSW or Queensland grain belts. Manufacturers of the eco weed mats are the textile industry in NSW and VIC.

Background
In an agricultural setting, weeds compete with productive crops or pasture for space, nutrients, water and light. Weeds reduce the productivity of otherwise productive land. UV-stabilised polyethylene films provide effective weed eradication, but also impede the effectiveness of rainfall and inhibit worm activity. Woven and spunlaced polypropylene fabrics allow water to pass through the fabric and thus solve the permeability problem. However, these petroleum-based materials are not biodegradable and contribute to plastic pollution.

Preliminary field trials indicate that for commercial horticultural growers, Eco Weed Mat is likely to be cost effective, technically ‘fit for purpose’ and offer benefits over non-biodegradable woven polypropylene products.
Aims/objectives
To evaluate the feasibility for commercial manufacture of biodegradable weed mats in Australia, including a survey of regional distribution of fibrous straw growth, fibre extraction technology, mat manufacturing technology and preliminary field trials to map how this initiative may create value in the regions.

Methods used
Preliminary samples and a 500 m sample of Eco Weed Mat was manufactured using CSIRO’s pilot scale nonwoven line. The samples were evaluated through laboratory testing followed by field trials. The testing and trial results provided the basis for feasibility assessment. The agricultural feasibility assessment included analysis of potential broad acre Australian fibre sources and cost estimates of raw material supply. Manufacturing feasibility assessment included estimation of fibre extraction costs, weed mat manufacturing technologies and weed mat manufacturing costs. Horticultural weed mat user feasibility assessment included field trials and cost benefit analysis of substituting Eco Weed Mat for conventionally sourced supplies.

Results/key findings
Eco Weed Mats were made from straw fibres using low cost and effective nonwoven manufacturing technologies. Laboratory testing and field trials demonstrated that the mats were thin but had sufficient strength for handling and can provide a biodegradable alternative for weed suppression.

Based on past fibre extraction activities in Australia, fibre suitable for weed mat manufacture can be extracted from linseed waste and provided to product manufacturers for $1000-$1300 per tonne.

Economic modelling showed that a 2.5m wide plant would produce an uncoloured (or black-dyed) weed mat at around $0.83 (or $0.88 dyed) per linear metre and retail between $1.60 and $2.50 per linear metre, competitive with current woven polypropylene alternatives. The plant would produce approximately 6 million metres of product, equivalent to around 10% of total estimated Australian weed mat use.

Preliminary field trials indicate that for commercial horticultural growers, Eco Weed Mat is likely to be cost effective, technically ‘fit for purpose’ and offer benefits over non-biodegradable woven polypropylene products.

Implications for relevant stakeholders
The project identifies a sustainable approach to the management of weed eradication and crop productivity.

The food-safe and biodegradable product provides new opportunities for the Agrifood sectors by avoiding negative impacts of chemical herbicides and petroleum-based synthetic weed mats.

The project identified agricultural straw wastes with potential for fibre extraction and the future of establishing a fibre extraction process to meet opportunities in a low carbon economy in Australia.

Eco Weed Mat provides business opportunities for the manufacturing sector in Australia.

Recommendations
The study results should be widely communicated to relevant stakeholders identified in this report.

More extensive broad acre field trials for different horticultural crops and landscaping species should be conducted.

Manufacturers and investors should be engaged to consider this business opportunity.

A strategic plan should be developed for the establishment of fibre extraction in Australia.

Australian government policies and assistance should be directed to assist industry to grasp opportunities offered by new plant fibres, through funding research and development of manufacturing technologies and applications.

Communications
Article published in Mansfield Courier.


A paper on the technical aspects of the project is being prepared for a peer-review journal, example, Bioresource Technology.

(PRJ-007154)
The Development of a National Weeds Resource Information Portal

Researcher/contact
Mr Chris Auricht
Auricht Enterprises
Dr Bertie Hennecke
ABARES
Dr Darren Kriticos
CSIRO
Mr Steve Dodt
Dodt.com studios
Dr David Low
Monash University

Where are the relevant industries located in Australia?
Industries/stakeholders span the width and breadth of Australia including a variety of sectors from Agricultural, to environment, government, research, educational, community and nurseries.

Background
Invasive plant species are considered one of the major threats to the sustainable management of natural resources. The total cost of the national farm weed bill is estimated to be $4 billion per year, made up of yield losses and control costs with additional costs associated with environmental costs such as impacts related to the long-term degradation of vegetation and biodiversity or impacts on health, safety, amenity, infrastructure, tourism and the general quality of life.

Research conducted with the wider weeds community indicates that significant issues exist with the quality and dissemination of existing information. Addressing this issue requires access to timely, up-to-date data in a user friendly format.

Aims/objectives
The aim of the current project is to develop an authoritative National Weeds Information System. To this end the vision is for a portal that provides mechanisms to capture, store and verify information on weed distribution, impacts and efficacy of management actions. In this respect the mission is to build an evolving collaborative environment to inform, educate, and interact with stakeholders, enhancing their capacity to prevent or control weeds.

What the report is about
The development of a national weeds information system. This research involved four sub-projects.

Who is the report targeted at?
This report is aimed at the broader weed management community including various levels of government, community, industry, education/research and non-government organisations.
This effort comprises a series of components:

Sub-Project 1: Coordination and Support, Mapping (Capacity and Standards) and Website construction

Sub-Project 2: High quality potential distribution datasets based on historical and future climate scenario for presentation on the weeds web site

Sub-Project 3: Establishment of a database information system to store and package weed related information

Sub-Project 4: Social Media and Discussion forums

Methods used
A series of methods were used.

Sub-Project 1: Coordination and Support – Achieved through numerous workshops, working sessions and teleconferences and email. Considerable effort was provided to ensure close links were established between projects and the management committee early in the project and maintained throughout. Additional support was also provided to underpin the development of a roadmap for the continued development of the national system.

Mapping (Capacity and Standards) - Workshops and working sessions held with various stakeholder groups aimed at raising the capacity of community groups to report weed related information. Existing material on standards has been collated and provided to the joint national indicators working group. Potential distribution dataset from sub-project 2 were converted into map products and made available as Web Map Services.

Website - Steve Dodt from Dodt.com was engaged to provide technical support, to scope architecture requirements, build the site and develop automated load scripts, and to automatically load information from Sub-project 3 into the web site.

Sub-Project 2: Niche models that have been documented in peer-reviewed journal papers or Government reports were collated and run with the CM10 1975H V1.1 historical climate dataset and the CM10 2070 CS A1B V1.1 (Kriticos et al., 2012). Where multiple models were available, the best quality model was retained. The 41 CLIMEX models (Sutherst et al., 2007) for the sleeper and alert weeds (Scott et al., 2008) were reviewed to assess whether there was any new literature or distribution data available, and where appropriate, the model parameters were re-fitted. The saved output was made available to Sub-project 1 to transform into web maps for the RIRDC Weeds Web Portal.

Sub-Project 3: Designed the data model and development of database. Collated and synthesised point-of-truth data and information on Weeds of National Significance (WoNS) from various sources that was collected and analysed. It also developed an output file for automated input into the web site.

Sub-Project 4: The importance of research papers and press releases in research communication is well accepted. Research publications and their associated press releases are understood to be a means to transform research into ‘stories’. These stories offer weed stakeholders new ways to become involved and to address weeds, or perhaps offer investment opportunities to businesses wishing to service these interests. To this end, The Weed’s News provided a large number of news articles about weed research on a weekly basis and disseminated these to 30,000 subscribers in a weekly e-digest form. The Weed’s News methodology was to repackage and circulate information from other sources, especially weed related academic journals and press releases arising out of such research. Additionally, the second component of the project set up an on-line discussion forum that could be subdivided into special areas of interest.

Results/key findings
Sub-Project 1: A draft National Weeds Information System has been established with general information on a range of nationally important invasive plant species. Material is available for both the original WoNS and new WoNS. An interim site has been set up at http://weeds.dodt.net.au/home/invasive-species/. Discussion forums have also been established for WoNS to enable social media type interaction and provide a conduit between WoNS coordinators and stakeholders.

Coordination has occurred between stakeholders, the various sub-projects (CSIRO – Potential Distribution, ABARES – Weed Information Packing, David Low – Social Media) and Steering Committee. Close liaison was also established and maintained with the Atlas of Living Australia creating positive synergies for both for access to data and adoption of standards.

Enhancements have been completed for a national weed mapping portal enabling community groups to report weed related information spatially at http://spatial.agric.wa.gov.au/weeds/v3dev/.

Sub-Project 2: Potential distribution models were run for 10 of the 20 original Weeds of National Significance (WONS), 6 of the 12 new WONS, and all 41 of the sleeper and alert weeds identified in (Scott et al., 2008). In all cases, the models represented the best quality models available in so far as they were documented, and included full consideration of the available ecological information regarding each species as well as its known distribution overseas and in Australia.

Continued...
The Development of a National Weeds Resource Information Portal (Cont.)

Sub-Project 3: Complete data has been made available for Bridal Creeper with general information available for all WoNS at http://weeds.dodt.net.au/home/invasive-species/.

Sub-Project 4: This project has become a dedicated online weed research news provider with an attached discussion forum. The projects performance metrics, orienting effects and structural (semiotic) features, falls into the realm of science communication. The following presents results and findings according to a) performance metrics and b) discussion forum.

a) Performance Metrics
These results indicate a steady increase in interest. As The Weed’s News is issued usually on a weekly basis, activity spikes occur on the day of issue. Of special note is the increasing interest from USA. If the trend in interest from USA audience continues, USA will shortly become the largest audience by country for the news feed.

Refined measures indicate that a large proportion of visitors spend time on the site and dig into a few pages on each visit. It was also found that the Australian readers are the most likely to re-visit the web-site and the most likely to read multiple pages.

Also of note is the low returning visitor rate. More than 50% of visitors visit the web-site only once and do not return. This, however, does not mean that The Weed’s News is not being read by this group. Rather, it may indicate that users only read the emailed digest and have learnt that there is usually little more detail to be found by visiting the story at the web-site.

b) Discussion forum

The discussion area was delivered to specification and on schedule. Unfortunately the discussion area did not perform as well as we would have liked. While users visit the area to have a look, very little on-line discussion took place. Despite a substantial and encouraging expansion of interest in the news feed, therefore, our efforts to encourage more discussion failed to make much difference.

It was suspected that users are reluctant to put forward personal or sectional interests in a forum that is science oriented. A balance in coverage is what users expect from a news feed. Added to this limitation, scientists seem to be reluctant to discuss their research on-line in a public forum.

To find out what might work better in terms of on-line weed discussion forums, the on-line social awareness activity was moved outward to encompass three new media: Facebook, LinkedIn and Twitter. This strategy is already proving very successful in terms of generating discussion and further visitation to the web-site. It has also helped draw in additional subscribers to The Weed’s News.

Although in operation only a short time, there were indications that these more casual areas for social networking will generate the on-line discussion sought.
Further, these new on-line social networking activity areas can be integrated with the website (e.g. articles are posted from the news feed to Facebook which creates both visits to the article via the website and discussion about the content of the article on Facebook).

The above new services should generate a very broad-based weed network and assist to generate on-line discussions about the subject-matters envisioned by RIRDC and the Web Portal Steering Committee.
Indeed, that Committee has identified the need for WoNS network members to have a special on-line discussion forum. Researchers consulted on this matter with Ms Hillary Cherry (Weeds Of National Significance Coordinator) who informed them that she is developing a communication strategy. The WoNS communication strategy should be completed late June, 2012.

Implications for relevant stakeholders

Sub-Project 1: Maintenance of the site – arrangements are in place to enable administrators to access and maintain the site in order to keep it up to date as a leading source of information on weed distribution and management.

Sub-Project 2: Additional resources are required to add potential distribution models and maps for additional weeds.

Sub-Project 3: Scope was confined to demonstrating the packaging of weed related information within a website. Additional resources are required to collate and present information for additional weeds.

Sub-Project 4: The best indicator of interest in this sub-project can be derived by reviewing which tags were selected by visitors to The Weed’s News (see figure below). Perhaps most noteworthy from the point of view of Australian policy makers, the WoNS tag was the sixth most popular tag visited.

It was beyond the brief of the project to assess and report on how the digital object so constituted was valued and judged by users, other than via a breakdown of visitor metrics. Thus, how the information shared via this project was used would require further research, possibly via ethnographic methods such as end-user interviews.
Recommendations

Sub-Project 1: Continued development of the site to include information for additional species (as per various national lists e.g. National Environmental Alert List, Agricultural Sleeper List, Target for Biocontrol list) and increased functionality e.g. data capture using mobile apps. Additional work on developing a national standard for reporting data quality as it relates to data capture (current distribution) and potential distribution would add considerable value. Additional functionality to enable authorised users remote / web access to update/edit information on the site.

Sub-Project 2: Potential distribution models developed to inform strategic weed management in Australia should be of the highest possible quality, given the available knowledge of the species. Such models should employ methods demonstrated to provide robust results when applied to the challenging task of modelling species potential distributions under novel climatic conditions such as those experienced outside of their native range and under future climate scenarios. When presenting these models they should be adequately documented and include an assessment of their overall reliability and the rationale for this assessment.

Sub-Project 3: Continued collation and presentation of information for additional species needs to continue.

Sub-Project 4: The recommendations made here are targeted at RIRDC and Federal weed program managers.

1. Set up a WoNS social media discussion area.

   The findings indicate that there is strong interest in WoNS and the findings support the view that social media services would provide a suitable place for on-line discussion.

2. Broaden scope of weed information & communication strategies.

   The findings indicate that a specialised intermediary news service succeeds in communicating weed related information to a large number of relevant weed stakeholders. Further, the findings suggest that such a service can be successfully integrated with a broad range of social media services, further expanding the scope and impact of Australian weed communication.

Communications

Coxinall Communications provided specialist communication inputs to the project.

Specific communication activities have been completed for various elements e.g. on-line discussion groups, on-line help for the mapping portal.

REFERENCES


(PRJ-007171, PRJ-006972, PRJ-006995 and PRJ-007077)
Dieback of Weeds of National Significance (WoNS): their cause and prospects for biocontrol

Reseacher/contact
Dr Rieks van Klinken
CSIRO

What the report is about
This report documents research aimed at understanding various dieback phenomena observed in several Weeds of National Significance (WoNS) species across Australia with the aim of identifying novel management approaches.

Who is the report targeted at?
Stakeholders interested in the management of athel pine, bellyache bush, bitou bush, European blackberry, mimosa (Mimosa pigra), parkinsonia, and prickly acacia.

Where are the relevant industries located in Australia?
This project is of national importance. It targets seven WoNS species. Athel pine, bellyache bush, mimosa, parkinsonia and prickly acacia impact and threaten much of rangeland Australia, including the arid interior, semi-arid black-soil plains, tropical savannas and the wet-dry tropics. Of these, all but athel pine are serious weeds for the pastoral industry, and all five impact the environment. The remaining two species principally impact the environment - European blackberry across temperate Australia and bitou bush in coastal dune systems of eastern Australia.

Background
Large inexplicable patches of dead plants of the various WoNS species have been observed across Australia since at least the 1980s. Traditional plant pathology techniques have revealed a range of potential pathogens in some instances. Novel genetic approaches were however required to properly understand the phenomenon.

Aims/objectives
The aim of this project was to apply the latest molecular technologies to assist in determining the cause of dieback in populations of seven WoNS species, with the ultimate goal of identifying potential novel management options.

Methods used
A national sampling regime was designed and implemented on populations of each WoNS species in each region where dieback has been reported. This included central and western Qld, central Australia, the wet-dry tropics, Victoria River District, coastal NSW and south-western WA. In each region the fungal microflora of healthy and dieback affected WoNS populations (in plants and soil) were compared using a metagenomic approach combined with traditional culturing techniques. This multi-disciplinary approach enabled us to better describe the distribution and importance of putative dieback agents in each WoNS species, and the potential role of other endophytes.
Results/key findings

The effects of dieback differed considerably between species. It was most widespread in parkinsonia, with deaths being widely observed in all regions surveyed across northern Australia. In fact, finding unambiguously healthy plants was often difficult. Mimosa is largely restricted to the wet-dry tropics and dieback symptoms in this species were noted across the three surveyed catchments, with the most spectacular dieback observed on a property where all plants had died back to the roots across many hectares. Major dieback events have been reported in the past decade for athel pine (Finke River) and prickly acacia (central Qld), but no clear dieback symptoms were found on athel pine during our surveys, and mostly sublethal symptoms were observed on prickly acacia. The extent of dieback in European blackberry in south-western WA was described for the first time and found to have resulted in widespread population collapses in the Warren and Donnelly river catchments. In contrast, dieback in bitou bush and bellyache bush was only observed in localised areas.

The mass-sequencing approach detected many more putative species than traditional isolation techniques alone. Furthermore, the use of metagenomic data to describe fungal community structure in host plants and associated soils was shown to be highly efficient in screening large numbers of samples cost effectively. It also lacked the biases associated with organism culturing. As expected, the fungal communities within individual plants were depauperate. In most cases a relatively small subset of putative species was strongly associated with dieback symptoms.

Preliminary results for bitou bush suggest healthy and diseased plants have very different endophytic fungal communities. Phomopsis sp. was dominant in diseased plants whereas Penicillin sp. dominated the healthy plant samples. However, there were no associated differences in soil fungal communities. The likely causative agents of dieback in the bellyache bush, mimosa, parkinsonia and prickly acacia all belong to the family Botryosphaeriaceae, although they were also sometimes present in apparently healthy plants. Data analyses are ongoing for all seven species.

Implications for relevant stakeholders

Understanding the causes of dieback in the various WoNS species will provide key knowledge to determine if the phenomenon is likely to persist and provide continued natural control for stakeholders, and whether it will realistically offer novel management options.

Recommendations

The natural dieback phenomenon continues to present exciting opportunities for developing novel management tools for some of Australia’s worst weeds. However, this phenomenon is not straightforward and realistically any development into novel management tools will require concerted effort. This one-year study provides an excellent conceptual, methodological and empirical basis for this.

Communication


Individual papers are also expected describing results from each investigated species.

(PRJ-007280)
National Weeds Spread Prevention Initiative

What the report (Initiative) is about
This initiative was commissioned by Department of Agriculture Fisheries and Forestry (DAFF) though RIRDC and seeks to implement goals of the National Weed Strategy through the development of policy and negotiation with weed managers across Australia. Please refer to the background section below for further information.

*Please note that this is NOT a research project and is therefore not seeking to find or develop solutions to improve weed management for a particular industry. The ‘methods’, ‘results and key findings’ sections of this report have been populated to reflect the nature of the initiative.

Who is the report (Initiative) targeted at?
The initiative initially targets state and territory policy makers to set a policy direction, and seeks a commitment from all state and territory weed agencies to that policy direction. A secondary and ongoing target audience is industry and other land managers.

Where are the relevant industries located in Australia?
This initiative applies to all industries Australia-wide that are either directly or indirectly affected by weed spread, have the potential to spread weeds, or could have the potential to assist in the early detection of new weed problems through reporting. This initiative is NOT limited to industry, in fact it is fundamentally about getting all levels of government throughout Australia to agree in principal to minimum standards to reduce weed spread and improve surveillance capabilities.

Background
Goal 1: the National Weed Strategy relates to prevention of new weed problems. The Australian Weed Strategy Implementation Plan identified eight high priority and 1 medium priority actions under goal 1 that require further progression. Three of these priority actions relate to early detection and two relate to weed spread prevention.

The National Weed Spread Prevention Initiative (NWSPPI) was established earlier this year by the Department of Agriculture Fisheries and Forestry to facilitate progression of these strategic actions. This initiative is being managed by RIRDC, who appointed Matt Sheehan as the national coordinator until 30 June 2012.

“This initiative is NOT limited to industry, in fact it is fundamentally about getting all levels of government throughout Australia to agree in principal to minimum standards to reduce weed spread and improve surveillance capabilities.”
### Aims/objectives

The National Weed Spread Prevention Initiative seeks to improve communication between stakeholders, share knowledge and get agreement on a framework that will increase the capacity for, and commitment to early detection and eradication of weeds by all major stakeholders (Government and industry) throughout Australia. The Weed Spread Prevention Initiative and work of the national coordinator should be viewed by states and territories as a resource that will assist them to deliver on their commitments under the Australian Weed Strategy.

### Methods used

This initiative is largely about communication and consultation. Below is a table detailing the key communication messages that are being delivered through the initiative and the method of delivery. This should be read in conjunction with the agreed NWSPI Workplan.

<table>
<thead>
<tr>
<th>Key message</th>
<th>Communication Activity/Method of delivery</th>
<th>Audience</th>
</tr>
</thead>
<tbody>
<tr>
<td>The National Weed Spread Prevention Initiative is a resource that will assist statutory weed authorities in each state and territory deliver on their commitments under the Australian Weed Strategy</td>
<td><strong>Face-to-face meetings/presentations</strong>&lt;br&gt;Engage at a policy/strategic level to promote the initiative, get input into its development and ultimately endorse tools that have been developed (frameworks, plans etc.)</td>
<td>All State/Territory Governments&lt;br&gt;NRM Boards (SA)&lt;br&gt;Local Government (NSW)</td>
</tr>
<tr>
<td>Weed spread poses a significant threat to industries throughout Australia and they have an important role to play in reducing that threat</td>
<td><strong>Seminars / symposiums</strong>&lt;br&gt;Present at state weed conferences and other relevant fora to promote the initiative</td>
<td>Weed Managers</td>
</tr>
<tr>
<td></td>
<td><strong>Email, teleconference/faceto-face meetings</strong>&lt;br&gt;Inform industry of the initiative and gauge their interest</td>
<td>Industry stakeholders&lt;br&gt;RDCs.</td>
</tr>
<tr>
<td></td>
<td><strong>Newsletter, twitter and other social media</strong>&lt;br&gt;Create new opportunities to engage with industry within existing weed networks, giving them the opportunity to be involved with the development of the initiative</td>
<td>Industry stakeholders&lt;br&gt;RDCs.</td>
</tr>
<tr>
<td></td>
<td><strong>Stakeholder forum</strong>&lt;br&gt;Engage with key stakeholders (industry, researchers, state governments, NRM regions etc.) to determine current levels of adoption of protocols, effectiveness, research gaps etc.</td>
<td>Researchers&lt;br&gt;Industry&lt;br&gt;Weed managers</td>
</tr>
<tr>
<td></td>
<td><strong>Publication</strong>&lt;br&gt;Based on outcome of stakeholder forum</td>
<td></td>
</tr>
<tr>
<td>A Nationally endorsed surveillance strategy will support state-led approaches to early detection and weed spread prevention and will provide tools to help weed managers including industry reduce the impact of weeds</td>
<td><strong>Face to Face meetings/presentations</strong>&lt;br&gt;Engage with the AG, AWC reps, state/territory Governments and industry to agree on content of the National Surveillance Framework</td>
<td>All State/Territory Governments&lt;br&gt;NRM Boards (SA)&lt;br&gt;Local Government (NSW)&lt;br&gt;Industry</td>
</tr>
<tr>
<td></td>
<td><strong>Seminars / symposiums</strong>&lt;br&gt;Present relevant fora to promote the framework and invite feedback</td>
<td>All Stakeholders</td>
</tr>
<tr>
<td></td>
<td><strong>Publication - The National Surveillance Framework</strong>&lt;br&gt;Disseminate framework following its endorsement</td>
<td>All Stakeholders</td>
</tr>
</tbody>
</table>
Results/key findings

Over the reporting period, working in collaboration with key stakeholders, the initiative will have achieved the following key outputs/immediate outcomes:

- A Draft National Weed Surveillance Framework has been written and endorsed by all jurisdictions through the Australian Weeds Committee for progression to the National Biosecurity Committee.
- Key communication messages around weed spread prevention have been identified to raise stakeholder awareness about the benefits of both preventing and reducing weed spread. Refer to the NWSPI Communication Strategy for further information.
- Papers published to communicate key output/outputs of the NWSPI in relevant journals/farm guides.
- Extensive engagement with industry, resulting in increased networks and communication, and an increased willingness and capacity to adoption protocols to mitigate the spread of weeds. Focus industries include the mining sector and the extractive industry.

Adoption of the National Surveillance Framework will lead to:

- A greater consistency in weed surveillance measures nationally.
- Improved reporting of new incursions.
- Improved surveillance networks.
- An increased understanding of the importance of the surveillance component in weed management.
- Identification of the ongoing infrastructure and resourcing requirements to support a national surveillance initiative.

Adoption of industry-wide weed surveillance guidelines/code of practice will lead to:

- Increased capacity and willingness to prevent new weed problems.
- Increased capacity for early detection, facilitating appropriate management.
- Increased involvement from industries in weed management in accordance with nationally agreed techniques.

Implications for relevant stakeholders

Policy makers: The National Surveillance Framework has set a policy direction for weed spread prevention and surveillance/early detection that will enable all jurisdictions to more easily, collaboratively and consistently meet their obligations under Goal 1 of the Australian Weeds Strategy. It has also identified the infrastructure that will is required into the future to support the national implementation of the framework, and made recommendations on how this infrastructure can be best provided/resourced.

Industry: Outputs from the initiative (Nationally endorsed surveillance framework, and several draft industry-wide codes of practice and case studies around weed spread) have clearly define the responsibility of industry in relation to weed management and provided them with tools and structures at a policy level to assist them in meeting these responsibilities.

Communities: No direct implications for communities within the reporting period.

Recommendations

The recommendations will form the bases of the national surveillance Framework and will be targeted at all relevant land managers throughout Australia.

(PRJ-008368)
The strategic direction of the National Weeds and Productivity Research Program and the research investments made by RIRDC were overseen by the National Weeds and Productivity Research Program Weeds Advisory Committee. Chaired by former Federal Primary Industries Minister John Kerin AM, the committee was comprised of representatives from RIRDC, the agricultural and Indigenous communities, and leaders in the fields of biosecurity and weed management.

**CHAIRPERSON**

**Hon John Kerin AM**
The Honourable John Kerin AM is a former Federal Treasurer, Minister for Trade and Overseas Development, Minister for Primary Industries and Energy and Minister for Transport and Communications. Mr Kerin chaired the interim Steering Committee for Stage 1 of the National Weeds and Productivity Research Program.

**MEMBERS**

**Dr John Virtue**
Dr John Virtue is Manager of the NRM Biosecurity Unit in Biosecurity SA. Prior to this role Dr Virtue was the Senior Weed Ecologist in the South Australian Government and was also associated with the selection of Weeds of National Significance.

**Mr John Thorp**
John Thorp is an agricultural scientist and extension officer who is a National Weeds Management Facilitator. Mr Thorp was Project Manager for the implementation of the National Weeds Strategy and Executive Officer to the Australian Weeds Committee. He also facilitated the development of the Weeds of National Significance and their subsequent management.

**Mr Matthew Kennewell**
Matthew Kennewell is the Invasive Species Coordinator for South Coast Natural Resource Management in Western Australia. He has worked for over ten years in National Parks, focusing on invasive species control and promoting ecological restoration of flora and fauna.

**Prof. Roger Cousens**
Roger Cousens is a Professor in the Department of Resource Management and Geography at the University of Melbourne. His major research area over 27 years has been the ecology and biology of weeds. Professor Cousens published the book *Dynamics of Weed Populations* in 1995 and places particular emphasis on population dynamics of weeds and competition between weeds and crops.

**Dr Rohan Rainbow**
Dr Rohan Rainbow is the Manager for Crop Protection with the Grains Research and Development Corporation, and has over 20 years' experience in agricultural research and communication.

**Dr Jeanine Baker**
Dr Jeanine Baker is Director of the Weeds and Pest Animals Section, Department of Agriculture, Fisheries and Forestry. Dr Baker has more than 10 years of experience working in the area of invasive weed species.

**Peter Langdon**
Peter Langdon has worked as a policy officer in the weeds and pest animals section of DAFF since 2009 where he provides secretariat services to the Australian Weeds Committee.

**Aunty Virginia Robinson**
Virginia Robinson is an Aboriginal woman of the Yuwaalaraay tribe of north-west NSW and currently works as the Aboriginal Cultural Heritage (ACH) Officer and the Yuwaalaraay-Gamilaraay Language teacher for the Dharriwaa Elders Group at Walgett.

**Philip Reader**
Philip Reader is a Bishopbourne-based industrial hemp producer and the chairperson of the Tasmanian Farmers and Graziers Association (TFGA) Weeds Standing Committee.

**Craig Burns**
Craig Burns is Managing Director of the Rural Industries Research and Development Corporation.
NATIONAL WEEDS RESEARCH

A summary of research outcomes from the National Weeds and Productivity Research Program 2011-2012