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Invasive plants and animals – contrasts and connections

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Keynote: Scientific improvement in the human dimension of invasive species

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This paper discusses two recent studies exploring the use of human science in the Australian approach to invasive species management. *The support of the Invasive Animals CRC, RIRDC and the Australian Department of Sustainability, Environment, Water, Population and Communities is gratefully acknowledged.*

The control of invasive species is largely about managing human behaviour. For effective management many decisions must be shaped: not only those of landholders or others who spread, or who fail to control, invasive species. Four examples illustrate the diverse human dimensions of invasive species management.

1. The lack of resources for management reflects community preferences, expressed through politics. Politics is also involved in under-enforcement or the failure to implement landscape-scale control.
2. Consumer choices of what they cultivate or what animals they protect produce many invasive species problems. The importance of emotional and cultural concerns is demonstrated by the furore over animal culls or the cultivation of much-loved well-known weeds.
3. Invasive species control depends on ‘voluntarism’: reporting outbreaks, investing labour and resources, cooperating in coordinated programs, even legal compliance, are all voluntary. Significantly, to be useful desirable voluntary behaviour must be sustained even in the face of difficulty.
4. The behaviour of government and industry bodies also needs to be managed and accountable to make it more likely that they will diligent and effective in their roles, and meet the challenges of coordination.

Key actions involve significant cost and effort – weed or pest animal control can require unrelenting work and a lot of investment. Spending your weekend controlling other people’s problems, rather than having time with family or friends, is a ‘big ask’. It is not only necessary to encourage the desire to do the right thing, people also need skills and resources to be effective – these too are human dimensions.

The application of the scientific method of theorising, implementing and experimenting, measurement and analysis, and synthesis under the scrutiny of peers has resulted in major improvements in biophysical and technical knowledge and methods. The approach is institutionalised in technical research, in widespread scientific qualifications, and in the peer review processes associated with invasive species technology and techniques. The results have been technologically impressive and economically productive, but behavioural issues limit the benefits. Unfortunately we do not have an equivalent scientific approach to the human dimensions of invasive species management. I draw upon two recent studies (and cite a number of other pieces of evidence) to support this view.

STUDY 1: WEEDS INSTITUTIONS

The study, Innovations in institutions to improve weed funding, strategy and outcomes, was commissioned by the RIRDC and delivered in 2012[1]. The researchers reviewed reports and studies and used interviews to identify institutional questions where research could make a contribution. Issues included the operation and effectiveness of weeds management, regulation and land management.

The report proposed “[a] vision of a radically different future” with a higher level of institutional effectiveness. The study documented regulatory and administrative arrangements, from the Constitution down to local administration. It considered strategies to alter human behaviour with respect to weeds, regulatory compliance, court cases, and some aspects of weed funding.

Footnote

[1] Martin, P., Verbeek, M., Riley, S., Bartel, R. and Le Gal, E. (2012). Innovations in institutions to improve weed funding, strategy and outcomes, Proposals for a national weed institutions research agenda May 2012 RIRDC Publication RIRDC 12/091 ISBN: 978-1-74254-433-5, at https://rirdc.infoservices.com.au/items/12-091.

The report identified five opportunities for significant institutional improvement.

- Opportunity 1. Institutional innovations to enable integrated 'front line' action.
- Opportunity 2. Strategies to increase available front-line human and financial resources.
- Opportunity 3. Streamlining weed governance rules and organisations.
- Opportunity 4. Embed scientific, continuous improvement in the management of people.
- Opportunity 5. Benchmarking and evaluating weeds institutions.

This paper focuses on Opportunity 4. Part of the evidence was the content patterns of papers presented at the Australian National Weeds Conferences, from the 1960s through to 2011. Up until the 1990s, human issues were largely absent. In the 1990s the topics shifted slightly towards human aspects, with Landcare emerging as a relevant consideration. By 2002, weed professional and researcher interests had shifted to consider working 'on' community to improve their effectiveness, mainly through diffusing expert knowledge and harnessing volunteers to deliver front-line control using science-led methods. This adjustment of focus towards people strengthened over the following decade.

> *By the 2011 conference, although a majority of papers still discussed control techniques (such as biocontrols, herbicides, mapping and mechanical controls), many papers dealt with the behavioural aspect of weed management. Two sessions were specifically set aside for such issues: 'Innovative Practices and Approaches: Community Processes' (12 papers); and 'Innovative practices and approaches: Policy and Strategy' (11 papers).*

The years have thus seen a gradual progression from ignoring the human dimensions of the management challenge, to identification that technical solutions involve human aspects, towards an approach that tries to understand how to harness volunteers and landholders. Whilst in recent years there is some concern shown for working 'with' the community, the dominant stance of the papers is working 'on' the community, through extension and promotion coupled with volunteer engagement. Many individual case studies are reported, but there is little evidence of the development of theory or best practices or disciplined collective 'learning from shared experience'.

The following is the main conclusion reached about institutional arrangements for improving theory and practice for human dimensions aspects of weed control.

> *A key consideration is what is missing from the weed governance discourse. Three things stand out. The first is that the focus on people issues is very limited overall, and certainly is not proportionate to the impacts that these issues have on weed governance effectiveness. An analysis of the themes for the 16th Australian Weeds Conference shows that there were 57 themes in papers that related to people, 67 related to weeds and production, 98 concerned with characteristics of plants, 176 concerned with planning issues, and 267 concerned with programmes[2]. Of the 57 papers that touched on human themes, one considered economics and another mentioned markets, five concerned communications, and one considered landholder engagement. Weed epidemiology and integrated weed management were the most considered issues. What is striking in this, as with other weeds conferences, is the absence of the scientific method being applied to the human dimensions of weeds.*
>
> *The second gap is that the community engagement focus is still largely an extension, rather than engagement or partnership. Across the world there has been a shift from extension paradigm (emphasising transfer of knowledge from science to science-user) towards community engagement and partnership[3]. Implicit in this shift are quite*

Footnotes

[2] Martin, P. (2008). Cross pollination or cross-contamination? Directions for informing the management of invasives with market-economy concepts. Keynote address, Proceedings of the 16th Australian Weeds Conference, eds R.D. van Klinken, V.A. Osten, F.D. Panetta and J.C. Scanlan, Queensland Weeds Society.

[3] See for example Oliver, P. and Whelan, J. (2003). Literature review: regional natural resource governance, collaboration and partnerships, Technical Report 45, Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management; and Thompson, L., Stenekes, N., Kruger, H. and Carr, A. (2009). Engaging in biosecurity: Literature review of community engagement approaches. Australian Government Bureau of Rural Sciences.

fundamental changes in the power relationships between the end-user and the science provider, and in the mechanisms that are used to give effect to this relationship. With this comes cultural change, including de-emphasis upon the scope and exercise of control by government agencies and by scientists. Whilst there is an enormous amount of on-the-ground engagement taking place in the weeds sector, this aspect of weeds governance seems not to have become a focus for continuous scientific improvement.

STUDY 2: HUMAN DIMENSIONS OF PEST ANIMAL CONTROL

During 2013, the Department of Sustainability, Environment, Water, Population and Communities commissioned an in-depth study of recipients of Caring for Our Country funding for the control of rabbits, foxes, feral pigs and wild dogs between 2008 and 2012[4]. That research included consideration of the human behaviour methods used 'on the front line'. The Department agreed for the data to be further used for the purposes of research on community action on invasive species[5]. This provided the opportunity to test some hypotheses from the weeds institutions study.

The investigation involved a stratified random sample of approximately a third of relevant *Caring* projects from around Australia. The investigation reviewed project documentation, conducted 97 in-field interviews, and evaluated best management practices, community engagement, and communications. Twelve interviewers working in teams of two administered a standard set of questions in face-to-face sessions with project applicants and stakeholders. Both quantitative and qualitative analyses were used. Further analysis is being conducted on the data. Later publications will provide a more comprehensive analysis of the issues. I will discuss here only the preliminary findings on human dimensions issues.

Twenty-three per cent of project managers reported that their projects increased participation in invasive animal control by landholders, 15–20 per cent reported increased participation by NRM organisations, the indigenous community and volunteers. The literature on engagement[6] highlights that achieving lasting engagement requires that participants feel that they can trust those they work with, that their actions can make a difference, that they are able to influence decisions, and that their efforts will be recognised. Such 'ownership' was evaluated as evident in 49 per cent of projects, possible in another 37 per cent and not evident in 14 per cent.

Absentee landholders and uninterested or resource-poor neighbours were highlighted as significant impediments to coordinated invasive animal control programs. Approximately two-thirds of project managers believed that they had engaged a sufficient number of relevant and motivated stakeholders in the projects.

Evaluators assessed whether the engagement strategies involved the right number and mix of stakeholders with sufficient motivation and competence. Evaluators believed this was true in approximately 50 per cent of projects and 20 per cent were assessed as having failed to achieve effective engagement.

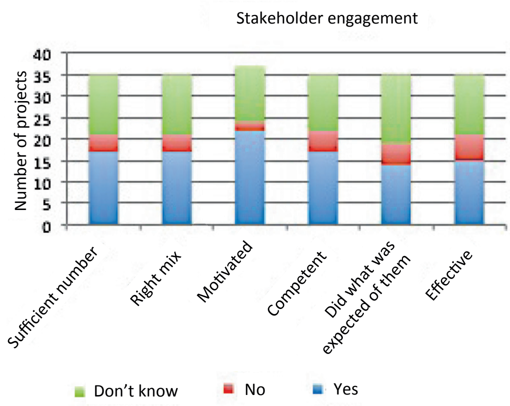

Figure 1. Whether stakeholders directly involved in the project were sufficiently engaged and competent.

Footnotes

[4] Martin, P., Verbeek, M. and others (2013). Measuring the Impact of managing invasive species. Report number K112-25, May 13 2013 for the Australian Government Department of Agriculture Forestry and Fisheries (contractor: Invasive Animals Limited, on behalf of the Invasive Animals CRC).

[5] Each interviewee also consented to this further use. UNE Ethics Approval No. HE12-103.

Footnote

[6] Lyndal Thompson, Nyree Stenekes, Heleen Kruger and Anna Carr op cit.

Evaluators asked applicants whether they developed an 'outreach' program to communicate information about invasive animal control to the broader community. Only six projects (17%) did not use an outreach program. Workshops and field days were the most common method followed by website, social media and newsletters. Also popular were press releases (9 projects) and websites, social media and newsletter (6 projects each). Ten projects used a combination of outreach methods; nine of these projects also used workshops/field days. Six projects that utilised websites also used social media and two of these used blogs.

As hypothesised from the weeds institutions study, engagement and communications strategies were generally not based on specific theories, research data or formal training. There was little evaluation of the effectiveness of these strategies, with only four using formal evaluation[7]. This is different to the technical aspects of invasive species control where practices are influenced by Best Management Practices, and disciplined evaluation is understood to be necessary. The Monitoring, Evaluation, Reporting and Improvement (MERI) requirement for Caring for Our Country projects added to the pressures for biophysical evaluation, but did not translate into human effectiveness evaluation. It should be noted that some individuals and organisations have developed sophisticated approaches, without the benefit of a scientific or institutional support structure, and without mechanisms to refine and spread best practices. That 'human dimensions' matters are neither prioritised by the institutional structures and project requirements, nor in the training of those who carry out the work, supports our earlier conclusion of an institutional deficiency.

A significant policy and practice development is an apparent shift in resources from the employment of front line extension officers towards digital communications. Whilst the numbers in our sample are small, none of the users of social media rated their use of digital methods as effective. The absence of objective data about the effectiveness of digital mechanisms prevents any firm conclusions being reached about whether these opinions are justified. A strategic shift towards digital engagement should be based upon a well-informed view that digital interaction is more cost-effective than interpersonal interaction. The literature neither supports such a conclusion, nor is there an indication that carefully considered strategic cost-effectiveness has been the basis for this shift. I do not suggest that properly designed digital interactions are ineffective, but these issues lend support to the view that the lack of a scientific approach to human interaction strategies is a serious deficiency.

The study supports the weeds institution study in showing a significant difference in the approaches taken to the technical aspects and the human dimensions of NRM. Technical invasive control has benefited from substantial scientific research investment over many years involving theorising, hypotheses development and empirical testing. This has resulted in well-developed and communicated technical practices (BMPs or equivalent) that should deliver reliable results. These form a foundation for further scientific continuous improvement. Practitioners have access to detailed guidance on how to develop and implement pest control strategies, and reasonably well-developed (albeit far from perfect or universally used) methods for empirical evaluation as part of continuous improvement.

The human dimensions are not subjected to an equivalent disciplined process of improvement. This is demonstrated in the practices of communications used in invasive animals management. Eighty-three per cent of projects evaluated invested in outreach, such as websites and blogs, factsheets and newsletters, opportunities for social media interactions, and training sessions. However very few (11%) projects conducted a formal assessment of the lasting benefits of these efforts, although comments from stakeholders indicated that outreach programs were seen to be important. There was negligible evidence of the use of explicit theory to inform 'human dimensions of NRM' practice. Few practitioners had specific training or referred to particular research-based materials to inform the design or implementation of these activities. There was negligible use of market research or any of the many other 'tools' of social science or modern management. This is quite different to the approach to technical aspects of control.

Observing that elements of a scientific method are lacking is not the same as saying that the work is

Footnote

[7] The formal monitoring was predominantly based on feedback rather than a design that would enable objective rating. Formal monitoring would also require project managers to define what they meant by the term 'effectiveness', an issue that was not raised by interviewees when asked to rate effectiveness.

poorly done, or ineffective. We saw many examples of impressive 'human dimensions' work, but history (even within the narrow confines of invasive animals control) demonstrates that the most reliable outcomes and the most rapid improvements arise when individual expertise and creativity is harnessed within a disciplined process of scientific continuous improvement.

The scientific approach to collective improvement depends upon dialogue between experts (often including informed practitioners) about specific theories that can be used to predict likely results from interventions or experiments (hypotheses), transparent methods and data, and presentation of explicit findings that feed back into the further development of theory. If this dialogue is not present, then arguably a field is not 'scientific'. The lack of cited studies as foundations for designing human interventions aligns with the patterns of the weeds institutions study. We have not yet done a content analysis of vertebrate pest conferences, but we expect that a similar pattern of dealing with human issues will be present, as we have observed for the weeds sector.

CONCLUSIONS

The conclusions are obvious. Despite a clear commitment to scientific continuous improvement in other aspects of invasive species management, and notwithstanding the strategic centrality of human dimensions of natural resource management, to date we have not given sufficient attention to well disciplined improvement in these key areas of performance. If we believe that the march of Science is the key to progress, then that view ought apply to all important aspects of invasive species management.

Determining the feasibility of training a dog to detect *Hieracium* spp. in the Victorian Alps

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Hawkweeds (*Hieracium* spp.) are 'daisy-like' plants native to Europe which have established as an environmental and agricultural weed in many parts of the world (Scott *et al*. 2001). Four species of hawkweeds have been found in Australia: orange hawkweed (*H. aurantiacum*), mouse-ear hawkweed (*H. pilosella*), king devil hawkweed (*H. praeltum*) and wall hawkweed (*H. murorum*).

Three species of hawkweed, orange hawkweed (*H. aurantiacum*), mouse-ear hawkweed (*H. pilosella*) and king devil hawkweed (*H. praeltum*), have naturalised in small populations in the Victorian high country, at Falls Creek Alpine Resort and the surrounding Alpine National Park, whilst orange hawkweed has also been found at Mt Buller. The Bogong High Plains at Falls Creek and associated alpine parks and reserves are recognised as places of national importance due to, in part, the unique flora and fauna that exist in these alpine environments.

The ability of hawkweed to spread rapidly and detrimentally alter floristic communities has been seen in New Zealand (McIntosh *et al*. 1995). This invasive ability has been recognised in Victoria, it is therefore declared as a State prohibited weed under the *Catchment and Land Protection Act 1994*. Hawkweeds have infested over 15 million hectares of land in New Zealand's South Island, and are now a common species on 42% of the high country, dominating vegetation cover over more than 500,000 hectares (Hunter 1991). Hawkweeds have also caused extensive degradation to a wide variety of habitats in central and north-western British Columbia, Canada. In the United States, the area infested by hawkweed is estimated to be expanding by 16% per year (Wilson and Callihan 1999), and costs stakeholders an estimated $58 million per year to control (Duncan 2005).

The three small, naturalised, hawkweed infestations in Victoria's high country are currently subject to long-standing eradication programs. Utilising teams of volunteers and contractors for surveillance, treatment and monitoring activities to search the extensive landscape. Each year, the understanding of infestations and their movement is becoming clearer, positively influencing decision making for surveillance and treatment. Over the past three seasons the number of plants found at Falls Creek has remained low, despite increased surveillance efforts. In recent years at Mount Buller very few plants have been found. Only three plants were found in 2012/13. This provides confidence that we may be drawing closer to eradication of hawkweed at this site.

Although the trend looks encouraging, the considerable time taken and low confidence levels to detect plants at the rosette stage are concerns, which is supported by Houser *et al.* (2012). Surveillance is also often challenged by thick vegetation in areas hard to traverse due to the steep and dangerous terrain, limiting the ability of humans to search such landscapes.

With these factors impeding surveillance, the Hawkweed Project Control Group is funding a trial to determine whether a dog can be trained to detect hawkweed as part of the surveillance and monitoring program. With their known heightened senses of smell, agility and ability to be trained, it is believed that a hawkweed detection dog could more efficiently and effectively find plants at the various stages of growth, including rhizomes, than humans. A detection dog may also be able to fast-track monitoring of known sites. As it may be able to quickly determine if any hawkweed plant material is present, and therefore influence the monitoring intervals of the site.

A professional dog trainer has been engaged to conduct a feasibility trial to establish if a dog can be trained to detect hawkweed, and if so, can it be trained to a level where false positives or false negatives do not occur?

Currently the hawkweed detection dog feasibility trial is in progress, with initial results being very encouraging. The trial results indicate a dog can be trained to detect hawkweed, and significantly, hawkweed rosettes. Positive indicators of the training are that the dog is already locating hawkweed in a range of vegetation types, and is exhibiting features of detecting the scent of the hawkweed from 20 meters away. This being a very positive sign as it means it has a strong connection with the scent. The training will continue until there is confidence that a dog can identify hawkweed 100% of the time during training sessions.

The second component to the training is to test the dog's ability to detect rhizomes and stolons. If this training proves successful, it will significantly expand the timeframe surveillance can be conducted. Integrating the dog into the monitoring program to detect stolons and rhizomes, which can lay dormant in the soil for long periods before producing a rosette. Whilst initial results are promising, it is hoped the next phase of the trial will provide the greatest benefit to our surveillance capability. The dog can already detect rosettes to a high level, and it is hoped that once fully trained, it will acquire the ability to detect stolons and rhizomes that should enable more effective detection, as these parts of the plant are suspected of containing a stronger scent.

If the hawkweed detection dog trial is successful, it could entirely change the surveillance approach for hawkweed. Supported by precise, targeted and effective treatment measures, the three hawkweed infestations in Victoria's high country may be far closer to eradication than previously thought.

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Changes to management of weeds and rabbits on roadsides

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Abstract The Victorian Government has moved to end confusion over who has responsibility for controlling weeds and pest animals on local roadsides. The Catchment and Land Protection Act (CaLP Act) has been amended to make it clear that municipal councils are responsible for most noxious weeds and for established pest animal control on municipal roads. Efforts to control roadside weeds and pests have been hampered by years of confusion among local councils and private landowners about who is responsible for control works on roadsides. The amendments made local councils the land owners of local roads for the purposes of the CaLP Act and allow for their responsibilities to be defined through roadside weed and pest management plans, approved by the Minister, which they will also be required to implement. Government assistance of $2.6 million per annum, over three years, had already been provided prior to the amendments. Local plans will be informed by public consultation and will ensure that coordinated action by community groups is supported.

BACKGROUND

The issue of managing weeds and pest animals on roadsides is principally regulated by the Catchment and Land Protection Act 1994 (CaLP Act). However, responsibility for controlling these pests is affected also by other legislation, including the Road Management Act 2004 and the Local Government Act 1989. From 2005, the Department of Primary Industries (DPI), the Department of Sustainability and Environment (DSE) and the Municipal Association of Victoria (MAV) had been examining the relevant legislation with a view to identifying who is best placed to deliver control operations for weeds and pest animals, and where responsibility resides for funding such activity.

The legal advice received by different organizations was not consistent and thus attempting to use legal advice to resolve this issue was not likely to prove effective. However, what was apparent from the legal advice was that current responsibility may vary depending on the category of pest and the status of the road. Thus, in some situations the Victorian Government may be responsible, while municipal councils may have responsibilities in other situations and some of these may be shared with adjoining landowners. From an operational perspective, this did not inspire confidence that the existing framework could provide for effective control of roadside weeds and pest animals in Victoria.

Given the complexity that had been generated by 15 years of incremental statutory amendments together with the release in 2010 of the Victorian Invasive Plants and Animal Policy Framework, it was recognized that it was timely to review the current situation regarding responsibility for controlling weeds and pest animals on roadsides.

WORKING PARTY

In June 2010, the Minister for Agriculture established a Working Party comprised of representatives of Government Departments, local government and primary producers, and independently chaired, to examine responsibilities for operational management of invasive plants and animals on roadsides and for funding such activities. Working Party members were drawn from the Victorian Farmers Federation (VFF), Municipal Association of Victoria (MAV), and three rural councils, the department and the former Department of Sustainability and Environment (DSE) now the Department of Environment and Primary Industries (DEPI).

Terms of Reference for the Working Party were:
'The Working Party on Management of Weeds and Pest Animals on Roadsides is responsible for collectively advising the Minister for Agriculture on future management of invasive plants and animals on roadsides in Victoria, within the context of the Invasive Plants and Animals Policy Framework.

The role of the Working Party was to:

- Commission an independent review to identify the costs, benefits and beneficiaries of invasive plant and animal management on roadsides and identify options for funding;

- Develop an approach to overall accountability, operational responsibility and funding based on the findings of the review, together with any other proposals from members; and
- Recommend to the Minister for Agriculture a consensus position that will provide for effective and efficient future management of invasive plants and animals on roadsides.

Pest animals that are of concern in this task are rabbits.'

The report of the Working Party was provided to the Minister for Agriculture in June 2011, was later made public on the DPI website and is currently available at http://www.depi.vic.gov.au/agriculture-and-food/pests-diseases-and-weeds/weeds/roadside-weeds-and-pests-report.

The Working Party's recommended future approach was that municipal councils should be required to provide some level of weed and rabbit control on roads that they manage, with the extent of works defined by individual local Plans. Cost-sharing with the Victorian Government was also recommended. The Government subsequently announced that it accepted the recommendation of the report that councils are best placed to control weeds and rabbits on local roadsides and would amend legislation to clarify that councils are responsible for controlling roadside weeds and, would financially assist them to address the challenge. This position was welcomed by some stakeholders, including the Victorian Farmers Federation. On behalf of local government the Municipal Association of Victoria opposed a legislated model and proposed instead a five year service agreement model to provide certainty to both the State Government and local government for the management of regionally controlled weeds and pests.

LEGISLATIVE CHANGES

Changes to the CaLP Act to implement the government's decision received Royal Assent on 24 September 2013 and were commenced on 18 November 2013. What follows is an overview of some of the main points; for a definitive statement of the provisions the current version of the CaLP Act should be consulted at http://www.legislation.vic.gov.au The changes to the CaLP Act only affect municipal roads; arrangements for roads managed by VicRoads are unaffected.

The legislation now makes municipal councils the landowner of municipal roadsides for the purposes of the CaLP Act, but allows for their responsibility to be limited to the preparation and delivery of a Plan for the management of regionally prohibited weeds, regionally controlled weeds and established pest animals on rural municipal roads. Specifically, the CaLP Act now requires a municipal council to prepare and submit to the Minister a Plan of between 2 and 4 years duration, for the management of regionally prohibited weeds, regionally controlled weeds, and established pest animals on rural municipal roads within the municipal district of that council, if the Minister declares that the municipal district is one to which the requirement applies. The existence of an approved Plan prevents any notices being issued by DEPI to require municipal councils to undertake additional roadside weed and pest control works and thus provides councils with certainty in budget planning.

A plan must set out a program of measures to eradicate, as far as possible, all regionally prohibited weeds and reasonable measures to be taken to reduce the adverse impact on surrounding land arising from specified regionally controlled weeds and established pest animals. The program of measures set out in a Plan must support programs that local land owners are running to manage weeds and pest animals and also protect the infrastructure and environmental value of roadsides. During preparation of a plan at least 28 days is allowed for public consultation, and the completed plan must be published.

FUNDING ARRANGEMENTS

Funding of $2.6 million per annum for the next three years was announced in the 2012 State Budget and is provided through the Department for Transport, Planning and Local Infrastructure (DTPLI) from July 2013. All eligible (non-metropolitan) councils receive a base funding amount of $5000 per year. Remaining funds are allocated based on the total number of kilometres of rural roads managed.

The maximum funding available per year (including the base allocation) is capped at $50,000 per council. A condition of this program is that councils do the work specified in a local plan prepared to the satisfaction of DEPI. These voluntary plans address the same matters and follow very much the same approach as the plans that councils can now be required to produce under the CaLP Act. Full details of the funding program are available at http://www.dpcd.vic.gov.au/localgovernment/projects-and-programs/roadside-weeds-and-pests-management-program.

CHANGEOVER TO THE NEW SYSTEM

The local roadside plans now in operation and the funding program that supports them are producing consistent and coordinated management, after many years of confusion and incomplete coverage of rural Victoria under earlier arrangements. The Minister has not yet declared any councils as ones to which the CaLP Act requirement to prepare a plan applies. To enable a smooth and efficient change to the new arrangements, councils will be allowed to complete plans prepared under the DTPLI funding program, which end in June 2015. Some of these councils may then be declared as ones to which the requirement to prepare a plan under the CaLP Act applies. In the case of councils with little or no rural road network the Minister can decide whether there is any need for a plan to be prepared. It is not anticipated that it will be necessary for DEPI to enforce control of weeds and pest animals management on municipal roadsides in a council area where the council is implementing a plan under the DTPLI funding scheme.

Demonstration of an unmanned aerial vehicle to detect alligator weed

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Abstract Detection of State Prohibited Weeds (SPWs) is critical for eradication programs to be successful. At a landscape scale detection of completely new infestations at an early stage of invasion is critical to improve eradication likelihood, and at a reduced cost. At a site scale patches of aquatic weeds are particularly difficult to detect from the ground because of swampy ground and tall emergent and riparian vegetation, e.g. common reed, cumbungi and blackberry. Obviously detection of all patches at a site is necessary to achieve eradication.

Recent advances in unmanned aerial vehicle (UAV) technology offer an opportunity to gain high spatial resolution aerial images of areas known, or suspected, to contain SPWs. Such images provide a 'birds-eye-view', eliminating the masking effect of tall non-target vegetation.

The results of a proof of concept project between Biosciences Research Division (BRD) of Department of Environment and Primary Industries (DEPI) and Australian Centre for Field Robotics (ACFR) (University of Sydney) will be presented.

The project used a UAV coupled with a camera to gain footage of Dandenong Creek. The ability of three methods to detect patches of alligator weed were compared:

1. intensive ground based surveys,
2. manually searching the images collected by the UAV, and
3. using an automated algorithm to search the images for the spectral signature of alligator weed.

The automated algorithm was able to detect and delineate patches of alligator weed growing along Dandenong Creek between >2.5–4 m^2 (area cover metric), while manual search of the images collected with the UAV could detect patches of alligator weed >0.06 m^2.

Using a UAV to collect images therefore provides a potential tool to detect patches of alligator weed at a scale useful for the alligator weed eradication program. Refinement of the algorithm is required before it is useful for detection of alligator weed at the site scale. Further development of the algorithm for alligator weed, and developing it for additional species, has the potential to be used in the detection of SPWs, with either site scale images, or to detect new infestations in landscape scale orthophotos.

INTRODUCTION

Alligator weed (*Alternanthera philoxeroides*) is declared a high priority weed (State Prohibited Weed) in Victoria, being targeted for eradication from the state. Currently alligator weed infestations in Victoria are concentrated within the Melbourne metropolitan region, although there are a few outlier infestations (Clements *et al.* 2011). Although current methods used for control of alligator weed are effective (Clements *et al.* submitted), a key impediment to the successful eradication of alligator weed and other high priority aquatic weeds is the ability to detect them so that control can be enacted. This ability is lacking at a landscape scale, i.e. detecting completely new infestations at an early stage of invasion and at a patch scale at a known infested site, i.e. detecting patches of alligator weed for herbicide treatment in a reach of creek known to contain alligator weed. For example, in the past decade there have been several accounts where large infestations of alligator weed have been found within the Melbourne region, but have not been detected at an early stage resulting in long term costs and associated problems caused by uncontrolled infestations (Clements *et al.* 2011).

Currently, the sole method used to detect alligator weed is on-ground human surveillance. This involves either on-ground field surveys or public and/or industry reporting of infestations. The former method is very resource intensive and is heavily reliant on an individual's ability to detect and document infestations. This detection method is limited by: availability of resources required for extensive on-ground field surveys; experience and training of personnel conducting the surveys; search effort required and timing of surveys; and in many cases inaccessibility of sites (e.g. swampy areas, steep terrain and dense vegetation).

Additional methods are required to supplement existing activities to enable improved detection of alligator weed and other aquatic State Prohibited

Weeds, including salvinia (*Salvinia molesta*) and water hyacinth (*Eichhornia crassipes*).

This project investigated the ability of an unmanned aerial vehicle (UAV) coupled with an on-board camera and post processing of recorded images with an automated recognition algorithm to detect alligator weed. UAVs are able to be equipped with cameras on-board to allow high quality, low elevation, geo-referenced digital aerial images to be taken at regular intervals. These images are then used to automatically detect particular features of an image by process of 'machine learning'. Machine learning is where a computer learns with data input and training, the ability to detect a particular feature based on algorithms. The algorithm aims to learn a model which describes the input-output relationship which can be used to predict the output on new input data. The development of this technology has previously been trialled on alligator weed (Sukkarieh 2009). However, no studies have verified the effectiveness of the currently employed algorithm learning on detection of alligator weed (Hung 2013).

This project aimed to conduct a proof of concept field trial to determine the ability of UAV technology and algorithm learning for detection of alligator weed and validate results based on intensive on-ground surveys.

METHODOLOGY

Trial sites Four trial sites were established south-east of Melbourne in March 2013, with alligator weed present in two different environmental situations and at different abundance levels.

Two sites had moderate abundance of alligator weed in a patchy distribution along an urban creek with floating mats of alligator weed (mats that extend over the water surface), as well as low levels of alligator weed in amongst dense emergent vegetation along creek banks. These two sites were located in an urban creek (Dandenong Creek, Site 1: 38° 0'19.51"S; 145°11'30.66"E and Site 2: 38° 0'30.34"S; 145°11'28.27"E). Both sites were similar, consisting of a linear 100–150 m stretch of creek, ~10 m in width (Figure 1A). The dense emergent vegetation along the banks of the creek consisted mainly of the native species *Persicaria* spp., *Typha* spp., *Phragmites australis, Schoenoplectus validus, Bolboschoenus caldwellii, Eleocharis sphacelata* and *Cyperus eragrostis*.

A further two sites had low abundance of alligator weed in a patchy distribution in amongst dense emergent vegetation in heavily vegetated wetlands. These two wetland sites were located in the upper reaches of the Patterson River (Site 3: 38° 2'3.63"S; 145°10' 55.89"E and Site 4: 38° 2'6.59"S; 145°10'55.45"E), adjacent to the Dandenong Creek. Both wetlands are disconnected from the main creek during low flow events and during this study were dry. The wetlands are relatively small (~950 m²) and contain similar dense emergent vegetation communities, consisting mostly of species from the Cyperaceae family (including *Schoenoplectus validus, Bolboschoenus caldwellii, Eleocharis spacelata* and *Cyperus eragrostis*) and lesser amounts of *Typha* spp. and *Phragmites australis* (Figure 2A).

UAV data collection A multi-rotor unmanned aerial vehicle was used to gather all the imagery used in this study. The UAV is illustrated in Figure 3. The technical specifications of the UAV are presented in Table 1. The UAV was flown autonomously in 50–75 m transects, and captured an image approximately every 6 m. The UAV made two transects per flight, with the first transect flown as an outbound leg and the second transect flown on the return leg. The images were collected using a down-ward pointing camera. Technical details of the camera are given in Table 2.

In this study, the aerial images were geo-registered using ground control points. Ground control points

Table 1. UAV technical characteristics. Note: this UAV is used for testing purposes only, for more extensive aerial survey techniques a larger aircraft would be used.

Make, model	Mikrokopter Hexacopter
Gross weight	1.5 kg
Dimensions	80 × 80 cm
Endurance	6 min.
Typical speed	1.0 m/s
Typical operating altitude	20 m
Typical range	<100 m

Table 2. Camera technical characteristics.

Make, model	Sony NEX 7
Resolution	6000 × 4000 pixels
Lens	16 mm f 2.8
Angular field of view	76 × 55 deg.
Typical footprint size	30 × 20 m
Typical spatial resolution	5 mm / pixel

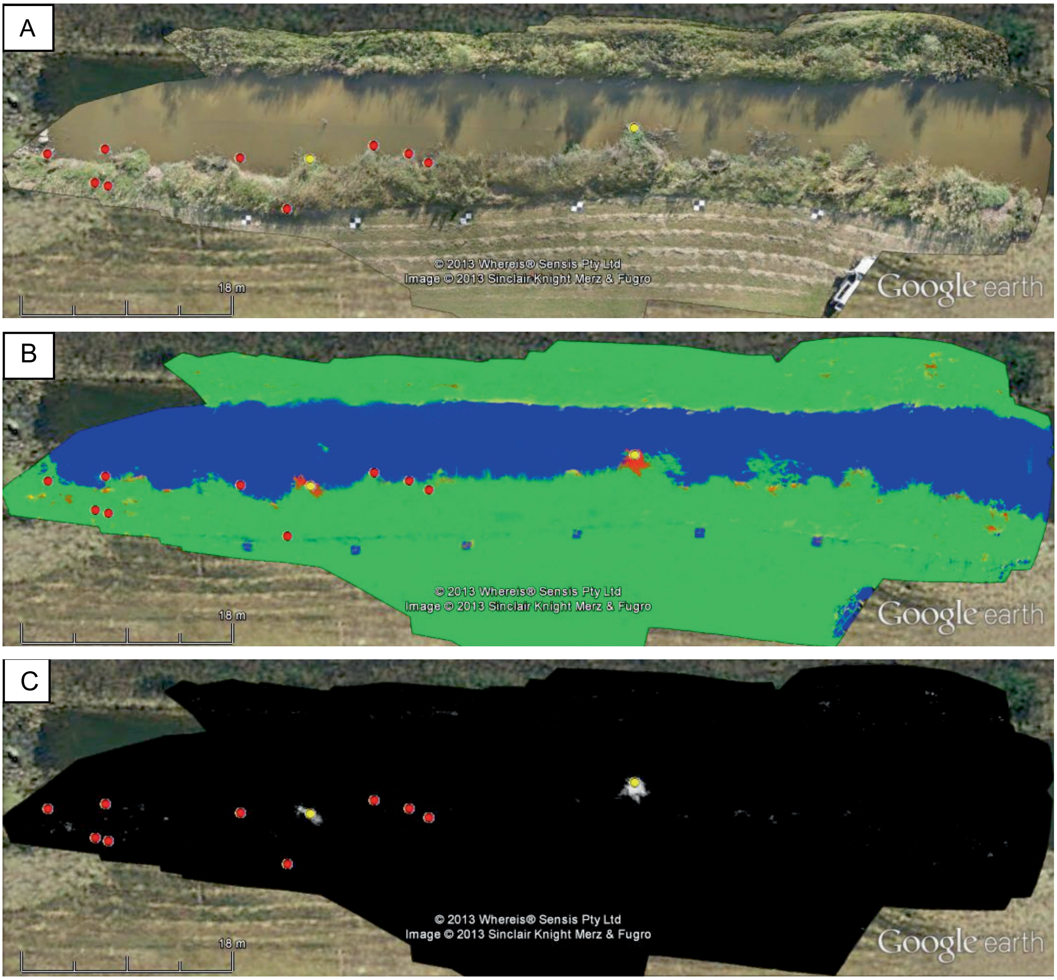

Figure 1. Dandenong Creek, Site 1. A) UAV aerial image with locations of alligator weed detected by the on-ground survey. Yellow markers indicate patches detected by UAV algorithm assessment, red markers indicate not detected by algorithm. B) Output from UAV algorithm; red patches = high probability of alligator weed; yellow = high probability of *Persicaria*; green = low probability of either species; blue = other. C) Probability that alligator weed is present. White = >80% probability of alligator weed present; black = <80% probability of alligator present.

are markers (checker boards) that can be readily identified in the aerial images, and whose position is accurately known. In this study, the markers were laid out at regular intervals, at a typical spacing of 10 m. The positions of these makers were surveyed using pseudorange-differential GPS.

Human surveying data collection Accurate mapping of the presence and abundance of all alligator weed at each site was undertaken by staff experienced in alligator weed detection (BRD). All mapping occurred within two days after UAV deployment (no flooding or other disturbance occurred during this time). For each patch of alligator weed detected,

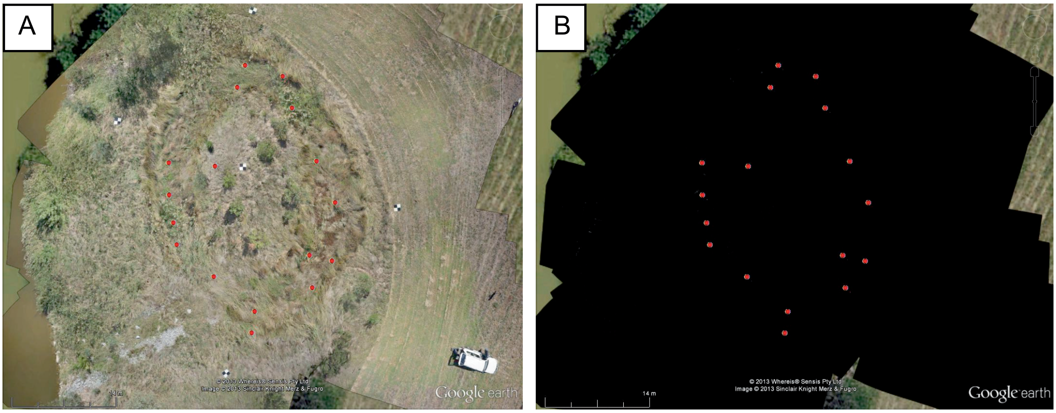

Figure 2. Patterson River, Site 3. A) UAV aerial image with locations of alligator weed detected by BRD's on-ground survey. Yellow markers indicate patches detected by UAV algorithm assessment, red markers indicate not detected by algorithm. B) Output from UAV algorithm; probability that alligator weed is present. White = >80% probability of alligator weed present; black = <80% probability of alligator present. Note: no alligator weed detected.

Figure 3. Mikrokopter Hexacopter multi-rotor UAV used in this study.

abundance and site description metrics were recorded.

The size of each patch of alligator weed was determined by measuring the maximum length and width of each patch and approximating it to the shape of an ellipse, from which an area was calculated. A visual estimate of alligator weed percent coverage, defined as the vertical projection of all plant material within the ellipse was made. The area (m^2) and cover (as a proportion) values were then multiplied to give a metric of alligator weed patch size, termed the area cover metric.

An accurate GPS waypoint was taken (<0.5 m accuracy; Trimble GeoExplorer 3000®) at the centre of each alligator weed patch. In addition the following was recorded for each patch: habitat position (over-water or along the water margin), orientation, associated vegetation present (species and associated heights) and a photographic record.

Within the week following the extensive on-ground survey by BRD, alligator weed along the Dandenong Creek (Sites 1 and 2) was sprayed with a broad spectrum herbicide (Roundup Biactive®: 10 mL/L) by experienced contractors (Thiess Services Pty Ltd), as part of the alligator weed eradication program. This provided an opportunity to assess the effectiveness of on-ground field control staff at detecting alligator weed. Effectiveness was assessed by BRD staff returning to the known alligator weed sites (from the extensive on-ground survey), within two weeks of herbicide treatment, and determining if herbicide had been used in the immediate vicinity of each patch for control of alligator weed.

Efficacy of alligator weed detection Image stitching and geo-registration was performed using off-the-shelf software, Agisoft PhotoScan. The geo-registration used information from: (1) the ground control point locations and (2) scale provided by the (known) size of the ground control point markers. A typical stitched and geo-registered map, overlaid on

Google Earth® is shown in Figure 1A. A qualitative assessment of the geo-registration accuracy can be made by noting the alignment of the river bank in the stitched map and what is shown by Google Earth®.

Each image taken by the UAV was geo-referenced and stitched together in post processing and converted to a Google Earth® file (.kmz), which formed the first stitched site image layer.

A subset of image patches which contained potential alligator weed and *Persicaria* were selected and hand labelled for algorithm training. Four classes were defined, alligator weed, *Persicaria*, vegetation other than alligator weed or *Persicaria*, and other (everything else). These classes were selected to evaluate the algorithm's ability to distinguish between alligator weed and other vegetation types and used to identify any performance improvement for future develop-ment.

After training the machine learning algorithm to model parameters, the algorithm was used to perform multi-class segmentation to classify the imagery collected. This inference process was applied to the original images to generate class probabilities for each class using every single image pixel. The class label on each pixel was then selected based on the highest class probability. These class-segmented images were then combined into a classification map using the same set of transformations for image geo-referencing and stitching.

After appropriate manipulation each layer was loaded into Google Earth® including the stitched site image, class layers (class and probability 80%) and GPS location for each site.

Using the stitched image for each site, aerial images were visually assessed to determine if each alligator weed patch (detected in the extensive on-ground field survey) could be distinguished. All visual analyses were conducted by the same interpreter to minimise variability due to subjective judgments. This was a test of the ability of an experienced person (BRD) to detect alligator weed patches with the low elevation UAV aerial images.

The same visual process was repeated comparing the alligator weed patches detected by the algorithm with those detected during the on-ground field survey. This was a test of the ability of the algorithm to detect alligator weed patches.

For both methods the ability to detect alligator weed was then related to abundance metrics (collected during the on-ground field survey by BRD) to determine the percentage of alligator weed patches detected and the minimum patch size detected based on area (m²) and cover (%) of each patch.

The on-ground survey conducted by contractors was assessed by comparing the detection rate achieved by the contractor surveys and the extensive on-ground field survey conducted by BRD.

RESULTS

Extensive on-ground survey (BRD) The on-ground survey conducted by BRD was used as the baseline from which the other detection methods were compared.

At Dandenong Creek (Sites 1 and 2) a total of 33 separate alligator weed patches were detected during the on-ground surveys (Table 3). Patches ranged from 0.003 to 8.6 m² (mean patch size = 0.86, SD 1.94) in area cover metric (Figure 4A); 0.008 to 12.3 m² absolute patch size and <5% to 80% cover. 73% of alligator weed patches were over-water, the remaining patches were located in amongst dense marginal vegetation.

At Patterson River a total of 28 patches were detected during the on-ground surveys (Table 4). Patches ranged from 0.002 to 6.9 m² (mean patch size = 0.67, SD 1.4) in area cover metric (Figure 5A); 0.008 to 19.7 m² absolute patch size and <5% to 35% cover. All alligator weed was present in amongst very dense (>85%) and tall (0.8 m average height) emergent vegetation.

Efficacy of UAV combined with visual detection The location of alligator weed patches at one of the Dandenong Creek sites is shown in Figure1A. At the Dandenong Creek sites, 45.5% of the alligator weed patches were detected by visual examination of the aerial images provided by the UAV (Table 3). All of these were over-water patches. This method detected 100% of over-water patches >0.06 m² (all areas reported hereafter are reported as area cover metric; Figure 4C) and 62.5% of all over-water patches.

None of the alligator weed present amongst dense marginal vegetation was detected. It was possible to differentiate between alligator weed and other species, including patches of *Persicaria* that float over the water surface and look very similar to alligator weed in most cases, depending on image quality. Successful differentiation between these two species required sharp images, which were not always obtained because of occasional rapid lateral movement of the UAV during wind gusts on the day of the flights.

The location of alligator weed patches at one of the Patterson River sites is shown in Figure 2A. Only

Table 3. Efficacy of methods used to detect alligator weed at Dandenong Creek (Sites 1 and 2 combined).

Detection method	Number of sites detected	Number of sites not detected	% detected	% not detected
Extensive on-ground survey (BRD) *	33	0	100	0
UAV image visual assessment	15	18	45.5	54.5
UAV algorithm assessment	3	30	9.1	90.9
Contractor on-ground survey†	16–23	10–17	48.5–69.7	30.3–51.5

* By definition this method is regarded to have detected all patches of alligator weed present at the site; we acknowledge some small patches may have not been detected.

† Value ranges are presented as some sites were not present during BRD post contractor survey.

Table 4. Efficacy of methods used to detect alligator weed at Patterson River (Sites 3 and 4 combined).

Detection method	Number of sites detected	Number of sites not detected	% detected	% not detected
Extensive on-ground survey (BRD) *	28	0	100	0
UAV image visual assessment	6	22	21.4	78.6
UAV algorithm assessment	0	28	0	100

* By definition this method is regarded to have detected all patches of alligator weed present at the site; we acknowledge some small patches may have not been detected.

21.4% of the alligator weed patches were detected when visually viewed from the aerial images (Table 4; Figure 5C). All of these patches were growing up through dense (>85% cover) and tall (0.8 m average height) emergent vegetation.

Efficacy of UAV combined with algorithm The classification of pixels to determine alligator weed detection is shown in Figure 4B and Figure 1C (site 1) for Dandenong Creek. Only 9.1% of the alligator weed patches were detected by the algorithm (Table 3). All of the patches detected were growing over-water and were ≥4.0m². No over-water patches were detected when patch size was ≤2.5m² (Figure 4B). An example of alligator weed detected and not detected by the algorithm is shown in Figure 6 and Figure 7, respectively.

Although the algorithm classified some areas amongst the marginal vegetation of the creek as alligator weed, none was clear enough to be credibly associated with a patch of alligator weed. This is because they were indistinct and often associated with other species that are not similar to alligator weed. These false-positives are shown as the white areas in Figure 1C.

In contrast the algorithm was on most occasions able to differentiate between alligator weed and *Persicaria*, which is a species that looks very similar to alligator weed (Figure 6). It can accurately determine alligator weed and distinguish it from *Persicaria* where the species occur within the same spatial zones of where positive samples were collected from. Thus we see the algorithm performing well at the sites that positive image samples were extracted from but nowhere else. A greater number of positive samples from a wider setting would improve the algorithm's performance and continue to allow it to distinguish between alligator weed and *Persicaria*.

No alligator weed was detected by the algorithm at Patterson River (Table 4; Figure 5B). This was not an unexpected result given the dense (>85% cover) and tall (0.8 m average height) emergent vegetation occupying the wetlands combined with low levels of alligator weed (<5 to 35% cover) growing in amongst the emergent vegetation.

Efficacy of contractor on-ground surveying The surveys by contractors occurred only at the Dandenong Creek sites. Unfortunately a small flood occurred between BRD's initial on-ground mapping and BRD's

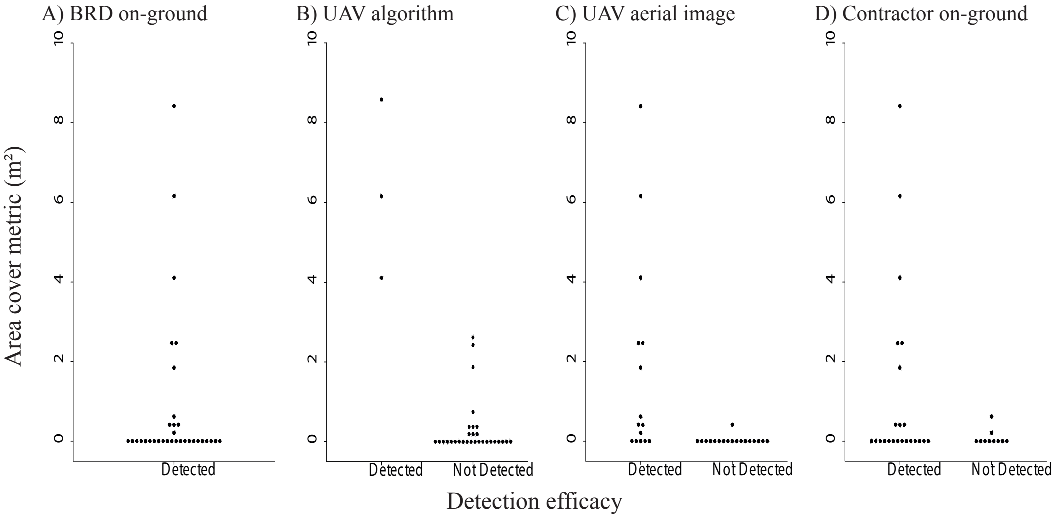

Figure 4. Size of alligator weed patches that were Detected or Not Detected for a range of methods used at Dandenong Creek (Sites 1 and 2 combined). Area cover metric (m²) = Area (m²) × cover (proportion). Many patches were <0.1 m^2 and appear on these charts as 0 m^2. Abbreviations: BRD = Biosciences Research Division. UAV = Unmanned aerial vehicle.

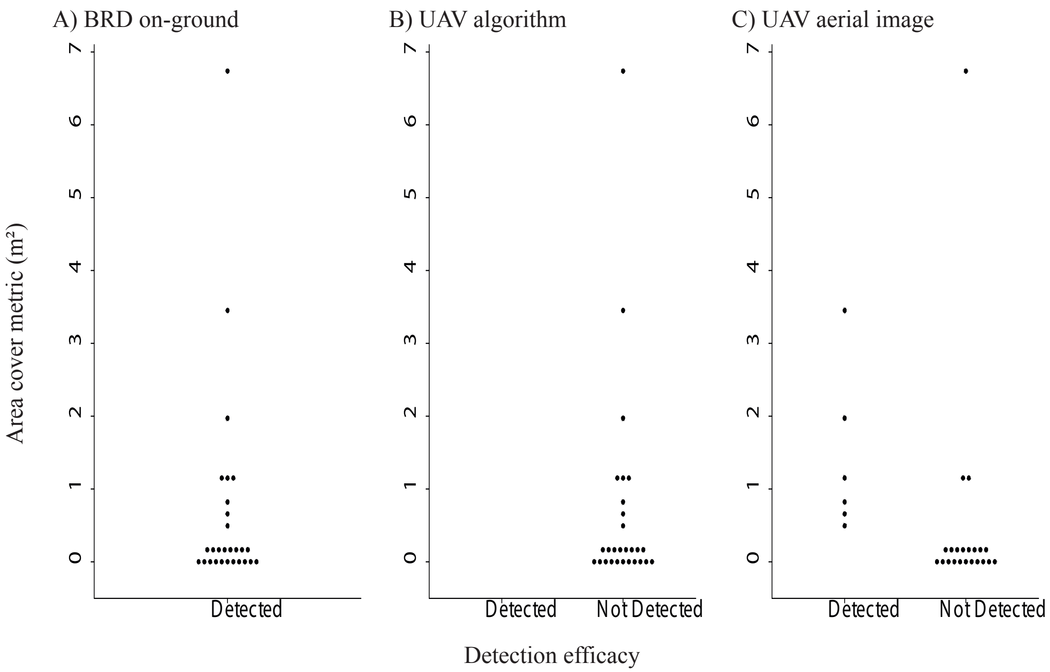

Figure 5. Size of alligator weed patches that were Detected or Not Detected for a range of methods used at Patterson River (Sites 3 and 4 combined). Area cover metric (m²) = Area (m²) × cover (proportion). Many patches were <0.1 m^2 and appear on these charts as 0 m^2. Abbreviations: BRD = Biosciences Research Division. UAV = Unmanned aerial vehicle.

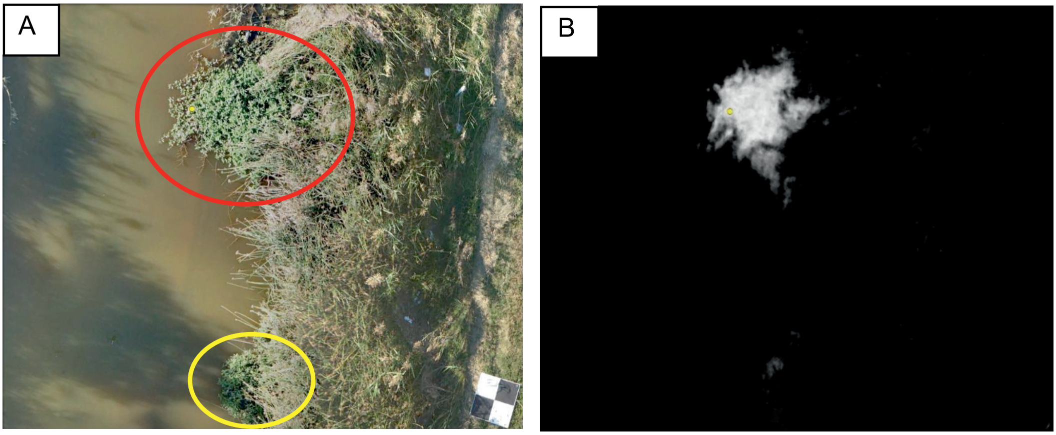

Figure 6. A) Patch of alligator weed >4 m² (red ellipse) and patch of *Persicaria* (yellow ellipse) at Dandenong Creek. B) Same area classified as alligator weed (white) and *Persicaria* (black) by the algorithm. Note: algorithm differentiated between alligator weed and *Persicaria*.

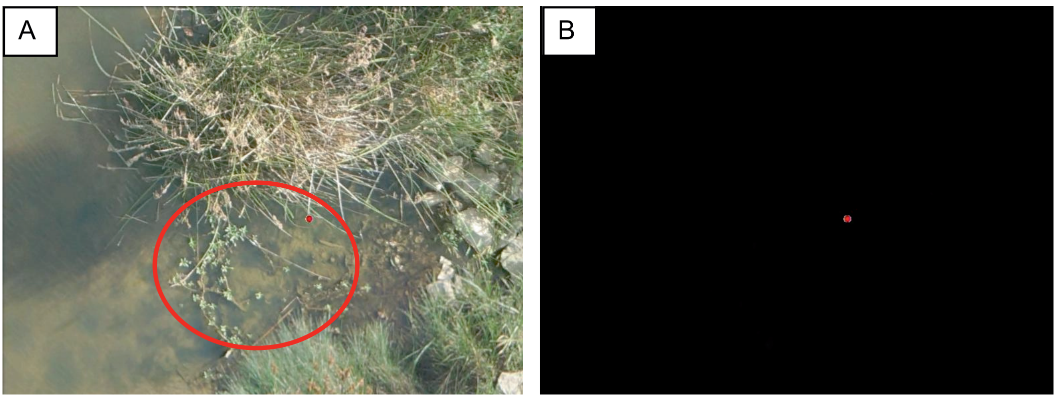

Figure 7. A) Patch of alligator weed <2.5 m² at Dandenong Creek. B) Example of alligator weed not detected by UAV algorithm. White = >80% probability of alligator weed present; black = <80% probability of alligator present. Note: No alligator weed detected by algorithm.

repeat mapping after the contractors had sprayed and the herbicide had taken effect. During this later mapping exercise 21.2% of patches could not be found, either because they had been dislodged by the flood or had completely died after herbicide application.

Despite this, 48.5% of the total number of patches had alligator weed that was clearly herbicide damaged. If we assume that the 21.2% of patches that we couldn't find were also treated, then 69.7% of alligator weed patches were detected and sprayed by the contractors (Table 3; Figure 4D). All of the remaining patches (30.3%) had healthy, untreated alligator weed present. Contractors detected all alligator weed patches that were >0.5 m², but only detected 30% of patches <0.35 m² (Figure 4D), regardless of habitat position (over-water or marginal). This was better than either the algorithm or manually searching images captured by the UAV.

DISCUSSION

Overall only a small proportion of the alligator weed patches were detected by the algorithm compared to the on-ground surveys conducted by BRD and the contractors. There are two important reasons for this. Firstly, the patches within these sites were mostly very small with low cover and were usually partially obscured by associated vegetation. Obstruction by other vegetation also makes detection of alligator weed difficult for human detection, requiring close observations from various angles. This low abundance reflects the advanced stage of the Victorian alligator weed eradication program. Secondly, because of this low abundance of alligator weed there was insufficient data to train the algorithm. In previous work by the ACFR for various invasive species programs a large set of data was collected and the algorithms have shown > 80% accuracy.

Despite these problems, we have been able to demonstrate that the UAV – algorithm system can be used to detect alligator weed patches at least 4 m^2 in size when they are growing over water. This size is small enough to be useful for detecting patches before they are too large to eradicate. Further, the UAV was able to collect images of high quality that allowed patches >0.06 m^2 to be visually classified, from over-water and marginal situations.

Biosecurity Victoria has a range of alligator weed patch sizes that they expect their contractors to reliably detect, depending on situation and priority. For Dandenong Creek, which is a low (3) priority site, their detection targets are 0.05 to 0.125 m^2 (area cover metric 1 m × 1 m × 5% cover to 0.5 m × 0.5 m × 50% cover, respectively) in clear landscapes and 0.8 to 2 m^2 (area cover metric 4 m × 4 m × 5% cover to 2 m × 2 m × 50% cover, respectively) in dense vegetation.

The threshold of ~0.06 m^2 achieved with the visual classification of the UAV images meets the current requirements of Biosecurity Victoria for the clear areas (~ over-water) and densely vegetated areas of this site. Cleary the algorithm in its current form doesn't meet these requirements, however with further refinement it is anticipated that improved detection levels will be possible.

Contractors found all patches >0.5 m^2 so exceeded their targets for a low priority site with dense vegetation. However, they missed 30% of patches <0.35 m^2, which included patches that were over-water.

CONCLUSIONS

1. Additional methods are required to supplement existing methods to enable improved detection of alligator weed and other high priority aquatic weeds. Images collected from low altitude aircraft (manned or unmanned) provide a reliable method to detect patches of alligator weed. Further, through an automation process, these images can be scanned and patches of alligator weed demarcated (although further refinement of the algorithm is required to improve detection rates).
2. High resolution low altitude aerial images taken by the UAV enabled patches of over-water alligator weed >0.06 m^2 to be visually distinguished. Alligator weed could not confidently be visually detected when mixed in amongst other dense vegetation.
3. Automatic scanning of aerial images with algorithm technology enabled patches of over-water alligator weed ≥4.0 m^2 to be delineated but was not effective when patches were ≤2.5 m^2 (there were no patches between these two sizes in this study) or mixed in amongst other dense vegetation.
4. On-ground contractor surveys were effective at detecting alligator weed patches that were >0.5 m^2, but were less effective (30% effective) at detecting patches <0.35 m^2.

ACKNOWLEDGEMENT

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Realising predictions about *Pittosporum undulatum*

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Summary *Pittosporum undulatum* was identified as an invader of forests and woodlands in southern Australia over 30 years ago (Gleadow and Ashton 1981). At the time it was predicted that its high reproductive potential, suppression of competitors, and broad tolerance of environmental challenges, coupled with changing management practices, could result in serious infestations and threaten the regeneration of native eucalypt forests, unless steps were taken to control it. That prediction is becoming a reality. At Menzies Creek, where there was a single female tree 70 years ago, the density of saplings and mature trees is now 4000–6000 per hectare; there is no diversity and no eucalyptus seedlings under the coalescing canopy. In order to determine the rate and direction of invasion in neighbouring areas, a good approximation of tree age is required. A citizen science project co-ordinated by one of us (JW) worked with the local primary school to calibrate plant circumference with age. Trees (N = 39) were felled 30 cm above ground level and age determined using tree rings at two sites; at the edge of the invasion canopy, and within it. The correlation between age and circumference was highly significant at both sites; however the slopes differed between trees growing at the edge and those growing in a closed canopy. Incorporating plant growth parameters into the invasive model will determine the time it will take for *P. undulatum* to invade non-managed forests in the region. It was estimated that the invasion front is progressing southward from Menzies Creek at about 80 m/year. If this rate applies to the *P. undulatum* populations now surrounding the Dandenong Ranges, then unless treatment or control measures are put in place, they will be completely covered in 25–30 years. The gender ratio of *P. undulatum* suggests that only about 25% of the population need to be treated or controlled — the female trees carrying viable berries — thereby reducing the cost of treatment greatly. While there are significant knowledge gaps in the area of population genetics, sex ratios and growth rates in different environments, it is important that coordinated action be taken soon to preserve the biodiversity of areas of significance to greater Melbourne and other areas of Victoria where its invasions have become well established.

INTRODUCTION

Pittosporum undulatum is a native tree species with a natural range from south-east Queensland to eastern Victoria. The Australian Virtual Herbarium reports that it was first identified in 1803 in Port Jackson (Sydney) and later in 1854 at Brodribb River (Orbost), Victoria (Mueller) and in 1884 at Studley Park in Victoria. It was inevitable that its sweet scented masses of white flowers in early spring and large orange berries in autumn would attract the attention of nurserymen and gardeners, so it became a popular ornamental tree in gardens throughout eastern Australia – from where it has spread. It is now well established outside its natural range in NSW, Victoria, Tasmania, South and Western Australia (Virtual Herbarium Distribution Map). Internationally, it has invaded significant areas of the Blue Mountains of Jamaica (Goodland and Healey 1996), the Azores (Laurenço *et al.* 2011), is an emerging alien invader in South Africa (Mokotjomela *et al.* 2013) and considered a nuisance in Hawaii, New Zealand, and the Norfolk and Lord Howe Islands (Gleadow and Ashton 1981).

In Victoria, it has invaded cool moist environments south of the Great Dividing Range and is well established throughout Gippsland, the Shires of Bass, Mornington, Cardinia, Yarra Ranges, Knox and Surf Coast and further west to South Australia. In the Shire of Yarra Ranges, it is particularly prevalent along its peri-urban fringe, where its most likely vector, the introduced blackbird, *Turdus merula* (Gleadow 1982) is highly active; it is the second most common weed after blackberries and is present in 50 per cent of reserves and roadsides (Smitka 2012). Data collected by Smitka also indicate that it has now invaded the entire perimeter of the Dandenong Ranges. Under current Victorian legislation, a native species cannot be declared a noxious weed, however, its invasiveness has now been recognised and it is classified as an Environmental Weed; its retail sale is prohibited. However, it has become widely established, and invasion can proceed without further plantings.

Gleadow (1982) predicted that its invasive characteristics and its wide tolerance of environmental conditions (Gleadow and Rowan 1982) would likely result in it becoming a serious weed tree unless steps were taken to control it (e.g. see Gleadow and Narayan 2007). Those measures were not taken, and that prediction has come to pass; it is a serious invader of remnant forests and threatens State and National Forests in Victoria and elsewhere. One of us (JW) was born in Menzies Creek, and knows that 75 years ago, there was only one *P. undulatum* tree in the entire village; it was planted around 1925. Now, 200 m from that original site, some 1200 seedlings (6000 ha^{-1}) have become established on a 2000 m^2 block of remnant forest, which had not been cleared for two seasons. On the two adjacent blocks of remnant forest, which have never been cleared, the density of saplings and young trees is 4–6000 ha^{-1}. This observation provided the stimulus to involve Grade 6 of the nearby Menzies Creek Primary School in a 'citizen environmental science' project. Now in its third year, a useful data set about the height, circumference and age of saplings and trees, the growth and development of seedlings, gender characteristics and biodiversity has been collected. In addition, the gender and fecundity of the flowers on trees were recorded, as this has been the subject of some discussion and may influence invasiveness (Mullett 1996). Incorporating these growth and morphological parameters into the invasive model should enable the time it will take for *P. undulatum* to invade non-managed forests in the region to be determined, while also assisting the development of effective and least-cost control programmes.

MATERIALS AND METHODS

Field sites and floristics Three sites were established in a remnant moist forest of *Eucalyptus obliqua*, near the Menzies Creek Primary School, 50 km east of Melbourne. The elevation is 300 m, annual rainfall is 750 mm and the soil is a medium depth kraznozem. In order to characterise the biodiversity at the site, the number of species present in 5 × 2 m quadrats along a 160 × 2 m wide transect across one of the study blocks invaded by *P. undulatum* were catalogued. This transect ran in an approximately north-west direction from higher ground near the watershed of the Cardinia (Western Port) and Menzies Creek (Yarra–Port Philip) catchments to the head of the south western limb of Menzies Creek, and Walker (2013) included both invaded and non-invaded areas.

Age–size determination The relationship between plant height, circumference and age was determined on 39 saplings and young trees along transects at two sites, one within 5 m of the canopy boundary (i.e. an active invasion front) and the second set 5–15 m inside the canopy. Saplings and young trees were felled 30 cm above ground, the circumference of the stump and height of each felled tree measured with a tape measure. Plant age was determined by counting tree rings. *P. undulatum* does not always form distinct seasonal growth rings so it is possible that the ages of a few older trees may therefore be in error by one or two years. Regression analysis was performed and curves of best fit calculated using Microsoft Excel. The Age data were then used to determine the direction of the invasion from the original planting at Menzies Creek, assuming that the youngest cohort of trees is furthest from the source; the rate of this invasion (m/year) was determined by dividing that distance, in metres, by 89, the interval in years (1925–2014).

Gender and fecundity The gender of 680 trees in eight locations between Boronia and Menzies Creek were determined from the apparent sex of their flowers in July 2013, as indicated by the presence or absence of stamens and styles. Fecundity was determined by the presence or absence of berries in November 2013 and February 2014. Berry density was scored as follows: Heavy (profuse bunches of 6–20 berries on most branchlets); Light (smaller bunches of 4–10 berries on many branchlets); Few (1–5 berries on a few branchlets); and None (no berries). Efforts were made to keep scoring consistent by following the criteria. Scoring was repeated at one site in February 2014 and was found to be concordant with earlier measurements.

RESULTS

Floristics In the 160 × 2 m transect running from Menzies Creek Primary School study site to the head of the south west limb of Menzies Creek, there were 10 *Eucalyptus obliqua* trees along the transect (312 ha^{-1}) and 116 (3635 ha^{-1}) *P. undulatum* seedlings, saplings and young trees. There were no *Eucalyptus* seedlings under the combined *Eucalyptus – P. undulatum* canopies while abundance and diversity in the understory under the coalesced *P. undulatum* canopy were low.

Age–size validation A strong correlation was detected between plant height and age, as determined by tree rings (Figure 1) for trees from both transects, plateauing when the plants reach about 8 m, close to the maximum height for this species, with correlation coefficients (R^2) of 0.935 and 0.854 for plants growing on the edge and under the canopy, respectively. The

Circumference × Age relationship, by contrast, was linear (Figure 2); however, the slopes of the Circumference/Age curves differed (Figure 2). Together, the height, circumference and age relationships presented in Figures 1 and 2 indicate that in the Menzies Creek environment, *P. undulatum* saplings and trees growing within the canopy were about 5 per cent taller, and the circumferences were significantly smaller, by 30 per cent, than those growing at the edge of the canopy. While more data are necessary to refine this relationship before it can be applied to all *P. undulatum* trees, the general relationship is strong. In practice though, it is generally sufficient to age a number of trees growing near the edge of an invasion front, so the relationship shown in Figure 2 for the 'edge' data is sufficiently predictive for use in an invasion model; in the Menzies Creek environment the circumference of *P. undulatum* trees are expanding at about 2.6 cm/year ($R^2 = 0.933$).

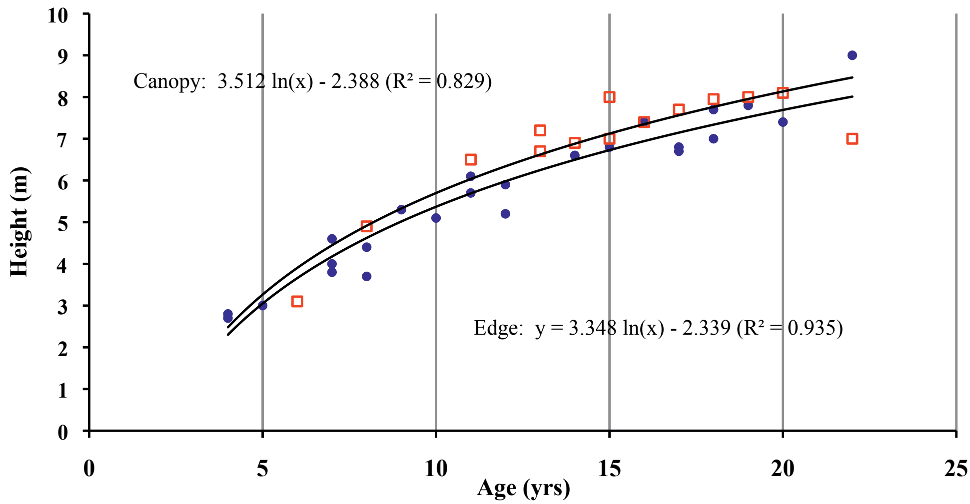

Figure 1. Relationship between height and age (as determined by tree rings) of *P. undulatum* saplings and young trees (N=39) recorded along two transects at Menzies Creek. Legend: □ Canopy, ● Edge.

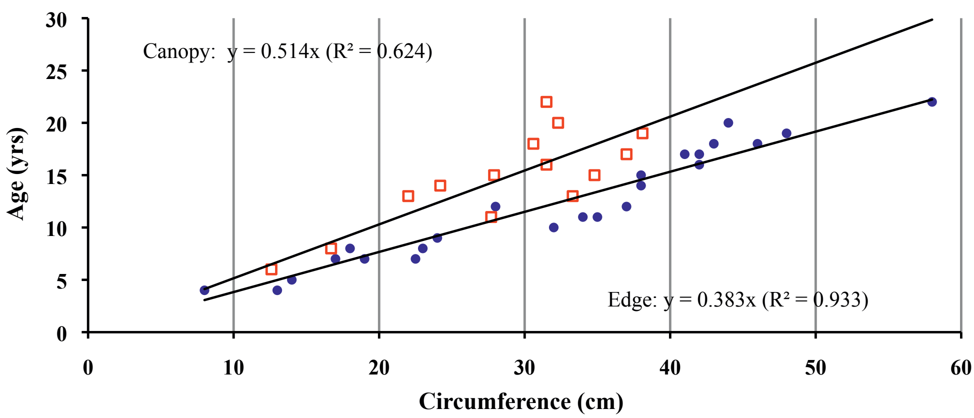

Figure 2. Relationship between age (as determined by tree rings) and circumference (at 30 cm) of *P. undulatum* saplings and young trees (N=39) growing along two transects at Menzies Creek. Legend: □ Canopy, ● Edge.

Direction and rate of invasion at Menzies Creek The age data presented in Figure 1 were used to determine the direction of the *P. undulatum* invasion activity in the vicinity of Menzies Creek. Its invasion front has progressed in a generally southern direction as the youngest cohort of seedlings and younger trees has reached beyond the southern end of the Cardinia Reservoir wall, along Wellington Road, 7.2 km from the original tree planted in Menzies Creek, about 90 years ago (around 1925). The rate of invasion has therefore been about 80 m/year.

DISCUSSION

Verification of age class determination General descriptions of *P. undulatum* list it as from 8 to 15 m tall with longevity of 40 years. One tree at Menzies Creek, outside the data sets reported here is 53 years old (Nitschke 2012, personal communication), 8 m high, 8 m wide and has a circumference of 180 cm. It carries a most profuse load of berries and invites description as a 'matriarch'. It is a daughter of the original 'matriarchal' tree planted in 1925. There are only three such trees among the thousands in Menzies Creek, a ratio which raises questions about the genetics of this invasive species. Height is frequently used to demonstrate age classes for *P. undulatum* (e.g. Gleadow and Ashton 1981, Mullet 1996), based on the assumption that it is indicative of age. Data presented here demonstrate that both height and circumference can be used as proxies for plant age. For plants between 5 and 10 years of age, height increased at approximately 0.5 m/year, but it increased by only about 0.1 m/year over the following 10 years. While the relationship between age and circumference is linear and therefore more suitable over a greater range of ages and sizes, it varies with habitat. This is not surprising, given the difference in available light. While *P. undulatum* is very shade tolerant, it cannot maintain high growth rates under dense shade (Gleadow *et al.* 1984). The circumference of *P. undulatum* trees growing near the edge of invasion fronts expands by about 2.6 cm/year so this can be used to assess the ages of similar trees and, in turn, their ages can be used to determine the direction and rate of such invasions.

Invasion rates and estimates of extent of invasions The rate of invasion in this study was estimated to be approximately 80 m/year. This rate is very much faster than the 30 m/year in the Blue Ranges of Jamaica (Goodland and Healey 1996). Even so, this 80 m/year rate of invasion in Menzies Creek may be an underestimate as no trees have been identified in the district older than 53 years and that tree appears to be extremely healthy and well short of dying; the next oldest are 40, 28 and 22 years, followed by a continuum to new seedlings. Gleadow and Narayan (2007) emphasized the role of fire in the survival of *P. undulatum*, so these apparent gaps in the age spectrum may possibly be due to periodic bushfires. The locality is a former farming district and farmers would most likely have removed any invasive plants on their properties but this would not explain the absence of *P. undulatum* within the nearby remnant forests; the causal factor may well be bushfire. It may also be possible that the behaviour of the main vector, blackbird (*Turdus merula*) (Gleadow 1981) plays a role in possible invasion surges. It is strongly territorial so if blackbird pairs defend their private source of berries, a neighbouring pair of blackbirds may need to wait until the invading *P. undulatum* population produces a new source of berries towards the edge of the competing birds' territory. Furthermore, blackbirds tend to nest at low levels and are therefore vulnerable to foxes, so the population of the vector could fluctuate across time (Walker, personal communication).

Areas to the west of this area, particularly in the Monbulk and Ferny Creek valleys are similarly being invaded (Smitka 2012). It is unlikely that the Cardinia Creek invasion could have originated from the west; there are only seven isolated older trees between South Belgrave and the Wellington Road roundabout (3 km) and none between that roundabout and the Cardinia Reservoir cohort, while there are thousands of seedlings, saplings and young trees in the continuum between Menzies Creek and the Cardinia Reservoir cohort. Once a beachhead has been established, *P. undulatum* can be a vigorous invader. A recent study of the Azores estimated, using aerial mapping, that *P. undulatum* was present in 62% of sites (Costa *et al.* 2012) and is now the most widespread invasive weed in the Islands (Costa *et al.* 2013).

Gleadow and Ashton (1981) foreshadowed the situation we see now where the Dandenong Ranges are essentially encircled by invaded forest. Yarra Ranges Council has mapped the weed distribution in all of its reserves and roadsides, and substantial populations of *P. undulatum* surround the Dandenong Ranges at Mount Evelyn, Silvan, Monbulk, The Patch, Menzies Creek, Selby, South Belgrave, Belgrave, Tecoma, Upwey, Ferntree Gully, Boronia, The Basin, Kilsyth, Mooroolbark and Montrose (Smitka 2012). The eastern and western boundaries of this encirclement are

4 km apart. The rate of the invasion in the Menzies Creek environment is about 80 m/year, so if this rate prevails in the entire Dandenong Ranges, then the existing invasion fronts will meet in about 25–30 years.

Numerous studies have shown that there is reduced abundance and floristic diversity in sites with high density of *P. undulatum*. (e.g. Gleadow and Ashton 1981, Gleadow and Narayan 2007, Mullet and Simmons 1995). Similar impacts on diversity have been observed in invaded forests in the Azores (Hortal *et al.* 2010). The absence of *Eucalyptus* seedlings under the *P. undulatum* canopy at Menzies Creek confirms these earlier studies and indicated that the eucalyptus ecosystem will be replaced progressively, and completely, by the mono-cultural *P. undulatum* ecosystem as mature eucalyptus trees die. Moreover, the process accelerates as the invading trees overtop the smaller trees and shrubs (Gleadow and Ashton 1981).

Gender and fecundity Invasive species often have a higher proportion of males to females (e.g. Wang *et al.* 2012). We found more male trees than female trees, and that the proportion of females declines from about 40 per cent to about 30 per cent between flowering time in early spring and the later development of berries. Significant also, the berry load of female trees varies considerably and this may also influence the overall reproduction rate of *P. undulatum* in this environment,

Table 1. Gender of *P. undulatum* flowers. Flowers were collected from trees growing at three sites in the Dandenong Ranges and their sex determined.

Location	N	Male	Female	M:F Ratio
Burwood Road, Boronia	47	27	20	57:43
Butler’s Road, Fern Tree Gully	44	26	18	59:41
Forest Rd, Lower Fern Tree Gully	62	39	23	63:37
TOTAL	153	92	61	
Gender ratio by flowers				60:40

Table 2. Fecundity of *P. undulatum*. The amount of fruit (berry load) on trees was estimated at four sites in November 2013 and January 2014. One site was reassessed in January 2014.

Late spring, November 2013	**Berry load***				
Location	N	Heavy	Light	Few	None
Menzies Creek School Study Site	74	3	5	16	50
Aura Vale Road, Menzies Creek	132	15	11	16	90
Railway Line, Menzies Creek	61	6	6	2	47
Selby Aura Road, Menzies Creek	61	4	5	6	46
TOTAL	328	28	27	40	233
Percentages		8.5	8.2	12.2	71.0
Gender ratio by berries			F: 29		M: 71
Mid-summer, January 2014	**Berry load***				
Location	N	Heavy	Light	Few	None
Aura Vale Road, Menzies Creek	132	13	16	10	93
Butler’s Road, Fern Tree Gully	70	11	10	4	45
TOTAL	202	24	26	14	138
Percentages		11.9	12.9	6.9	68.3
Gender ratio by berries			F: 31.7		M: 68.3

* Heavy: 6–20 berries on most branchlets; Light: 4–10 berries on many branchlets; Few: 1–5 berries on a few branchlets); None (no berries).

particularly as the vectors are probably more likely to visit those trees with heavy berry loads rather than 'waste time' hunting for sustenance on trees carrying lesser berry loads. This gender ratio suggests that only about 25 to 30% of the population would need to be controlled — those carrying berries — as distinct from the 40% that bear female flowers, thereby reducing the cost of control in terms of both funds and labour; trees in any given target location could be marked during the berry season and the labour to treat or remove them spread across the subsequent year. Mullet (1996) also reported a higher proportion of male trees in her study areas on the Mornington Peninsula, although she noted that some apparently male trees did sometimes have a few berries. The Menzies Creek students noted that many of the berries in the 'Few' category of this study rotted before reaching maturity. The viability of the different categories of berries will be resolved in a forthcoming study; any differences would influence control considerations.

Anecdotally, there is a belief in the community that *P. undulatum* is an important habitat for the powerful owl (*Ninox strenua*) and therefore that it should not be controlled. While it may well provide such a habitat, the argument can be posed about what species provided its habitat before this invasion. It seems likely that it was blackwood (*Acacia melanoxylon*) and since many blackwood trees are extant in and near these remnant forests, *P. undulatum* is superfluous for this function. If it is to be controlled and if only the female trees, or up to a maximum of about 30% of the population, need to be treated or removed, the majority of remaining male trees would provide habitat for the owl; there would be a long period of time for the powerful owl to adapt to the gradual decline of the male *P. undulatum* population.

CONCLUDING REMARKS

The example of *P. undulatum* raises questions about what constitutes a 'natural distribution'. In the Sydney basin, for example, there are records of *P. undulatum* going back to the early settlers, yet its increase in density, particularly in wet gullies in remnant urban forests is reducing biodiversity (Rose 1997). Implicit in this discussion is that 'native' is taken to be synonymous with pre-European distribution, even though this says nothing about its ecological requirements in space and time (Head and Muir 2004). This distinction will only become more difficult as the climate changes and the historical location is no longer suitable, or new areas become available for colonization (Gleadow and Ashton 1981, Webber and Scott 2012). In the case of *P. undulatum*, there is no doubt that the reduction in relatively hot forest fires and the introduction of avian vectors, have aided its spread. If the rate of the *P. undulatum* invasion from Menzies Creek during the past 90 years is relevant for the entire Dandenong Ranges, then they will be covered with *P. undulatum* in about 25 to 30 years and biodiversity will likely be lost unless the issue is recognised and appropriate control measures put in place. As a first step, females with high fecundity should be identified and removed. Areas that can be safely burnt should be managed in that way, although it is not completely effective and follow-up weeding would be required (Gleadow and Narayan 2007). As Gleadow and Ashton concluded in 1981: "The invasion of forest remnants by *P. undulatum* and other weeds is threatening the survival of the eucalypt forests in urban areas".

The participation of pupils from the Menzies Creek Primary School in this citizen science project demonstrates that simple measurements can be made that add substantially to the body of knowledge and can also act to engage students in science, and help them understand the need for environmental management in order to maintain biodiversity in their region.

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Yarra Ranges Council Weed Mapping Program 2010–13

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INTRODUCTION

Yarra Ranges Council is home to a population of around 145,000 people and covers an area of approximately 2500 square kilometres. Located on metropolitan Melbourne's eastern fringe residents and tourists are drawn to the iconic natural beauty of the municipality, with its diverse and unique landscapes providing critical habitat for many endangered species. To protect and enhance these natural values, Council carries out a suite of management activities each year across Council-managed bushland reserves, including weed control, revegetation, fuel reduction works, trails and asset maintenance, and protection of threatened species. Works are programmed annually at 138 bushland reserves (545 ha) and 354 roadsides (458 km), involving prioritisation and planning to make the best use of finite Council resources. In addition, separate weed control programs target high priority weeds in un-programmed sites, and more than 400 weed-related customer requests are actioned each year.

In 2010–11 Council developed a strategic weed mapping and monitoring program to measure the success of its weed management programs. This mapping method aims to balance time efficiency and practical application with scientific accuracy. Council selected sixty-two sites to map annually as 'flagship sites' that form a good representation of the bushland conservation sites on Council reserves, roadsides, trails and drainage easements All other programmed sites are mapped on a three-year rotation basis.

Council bushland managers, community groups and contractors use the resulting data to assist in the prioritisation of on-ground works. At the end of each financial year, data are collated into a report to identify trends and allow analysis of weed management techniques across Council's bushland sites. This allows Council to measure its effectiveness against its objective – which is to improve the proportion of bushland reserves and roadsides classified with a high or very high conservation rating by a 1% increase on the previous year (Refer to Appendix 1).

METHODOLOGY

Conservation Value Mapping Council's Weed Management Officer uses a GPS unit to create zones within a bushland reserve or roadside, with each zone having a different 'Conservation Value' based on a number of criteria mapped onsite including tree canopy cover, understorey cover, percentage weed cover, regeneration, organic matter, patch size, vegetation linkages and site disturbance.

The map on the following page (Figure 1) is an example of Polygon Mapping using the 'Conservation Value Mapping' method for one of our bushland reserves. Zones are allocated according to vegetation condition, distinct paths and tracks, and property boundaries.

After the individual zones are mapped, a GPS unit is used to make an assessment record of ecological characteristics, using drop down lists of weed species present and treatment methods.

Each zone is assessed for weed coverage and its quality of native vegetation, similar to a simplified habitat hectare model.

The data is provided to bushland team staff, contractors and environmental volunteer groups to help program works that will feed into annual management plans and achieve a more efficient approach towards weed management.

The mapping method records the following data for reserves and roadsides:

- zones of similar quality and vegetation class,
- ecological Vegetation Communities (EVC) and conservation status,
- species of weeds present and percentage coverage,
- conservation value and score,
- links to surrounding vegetation,
- cultural heritage overlays,
- preferred weed treatment methodology, and
- presence of regeneration.

This method provides the bushland team with information to analyse data across all bushland reserves and roadsides within Yarra Ranges and to strategically plan improvements to the weed management program. The field assessments provide the following:

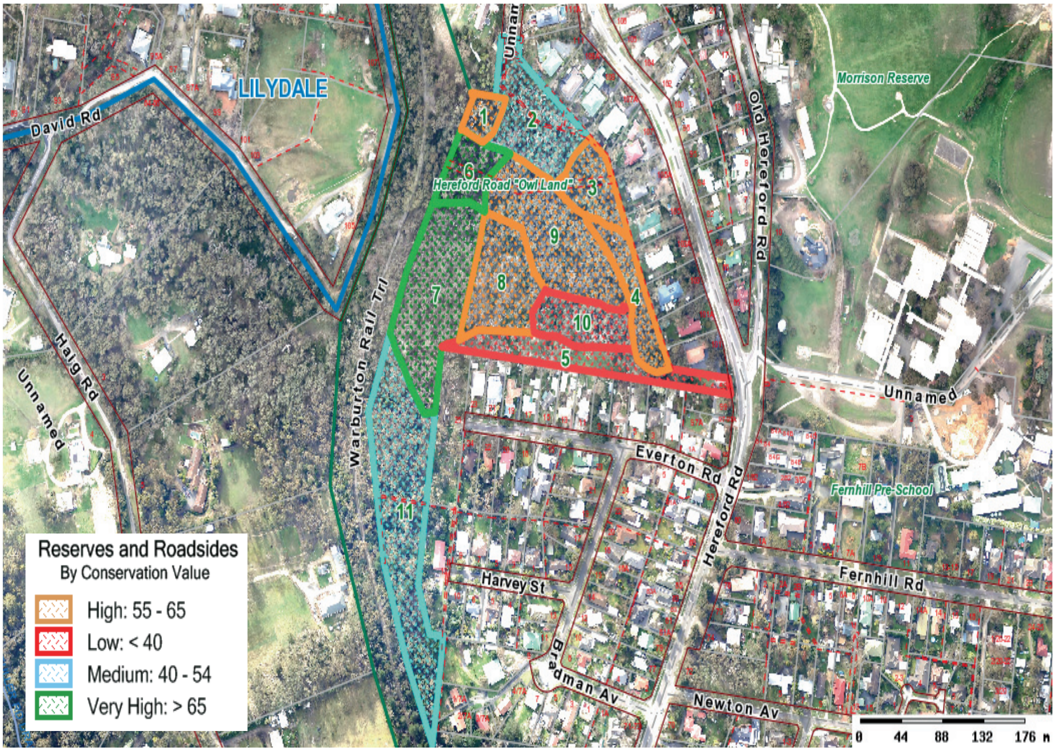

Figure 1. Zone mapping for Owl Land, Mt Evelyn.

- identification of the highest value biodiversity assets and major weed threats,
- prioritisation of weed control activities, and
- integration of weed management programs with other land managers and community through information sharing.

RESULTS

A total of 545 ha of 138 programmed bushland reserves and 458 km of 354 programmed bushland roadsides have been mapped from 2010–13.

The following chart (Figure 2) represents the conservation value of selected flagship bushland reserves for 2010–13 utilising the 'Conservation Value Mapping' method.

There has been a 3% improvement in both Very High and High conservation value bushland in selected flagship reserves over the three year program. In 2012–13, there has been a 1% improvement in selected flagship roadsides.

Weed coverage has seen a gradual decline, and blackberry remains the most threatening weed species.

SUMMARY

The key benefits of the weed mapping program are:

- Areas of conservation and biodiversity significance are identified.
- Data is available on weed species present, percentage cover, threatening processes, presence of regeneration, vegetation links, ecological vegetation communities, conservation status and rare species present.
- The spread of weeds is measured for actions to prevent new and emerging threats.
- Information is made available to assist bushland staff to set annual works programs, prioritise work zones and ensure efficient allocation of resources.
- Detailed information and maps provided to contractors, community groups and in-house staff

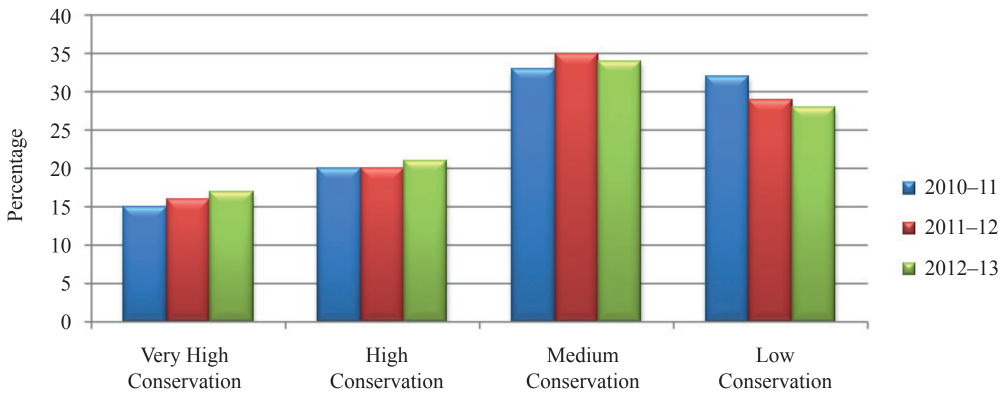

Figure 2. Conservation rating of selected flagship bushland reserves.

allow for improved planning and implementation of works.

- Long-term monitoring of weed management practices measures the effectiveness of these measures, and long-term monitoring of bushland condition measures effectiveness of weed management programs.

Appendix 1. Conservation Value Mapping.

Attribute	Description	Score
Tree canopy cover (-2, if unhealthy/ non-indgenous)	<10%	0
	10–25%	5
	25–50%	10
	50–75%	15
Understorey % cover	0–1%	0
	1–10%	5
	10–25%	10
	25–50%	15
	50–75%	20
	75–100%	25
Weed % cover	>50%	0
	25–50%	5
	5–25%	10
	<5%	15
Regeneration	Absent	0
	Present – Low	5
	Present – High	10
Organic matter (-1, majority not native logs and leaf litter)	<10%	0
	10–50%	5
	>50%	10
Patch size	<5 ha or 1–5 m	2
	5–20 ha or 5–20 m	5
	>20 ha or >20 m	10
Vegetation link	No surrounding veg.	0
	Partly surrounded veg.	3
	Fully surrounded veg.	5
Site disturbance	Highly degraded	0
	Substantially modified	2
	Moderate disturbance	5
	Near natural	10
Final Assessment Score (/100)		

Conservation Value: Very High >65, High 55–65, Medium 40–54, Low <40

Environmental Works Toolkit

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The Environmental Works Toolkit is a set of tools for managing works for the conservation of native vegetation. It includes manuals, factsheets, templates, recording sheets and other tools for prioritising and planning works, mapping weeds and rabbits, engaging contractors and reporting outcomes.

Three years ago, at the start of a four-year landscape-scale weed management project, a network of government agencies working in the Warrandyte to Kinglake Habitat Corridor realised the need for this consistent set of tools. At the start of the project, planning was site based, all project partners used different methods to map weeds and there was no practical way for the project to report results. From this problematic start rose the Environmental Works Toolkit.

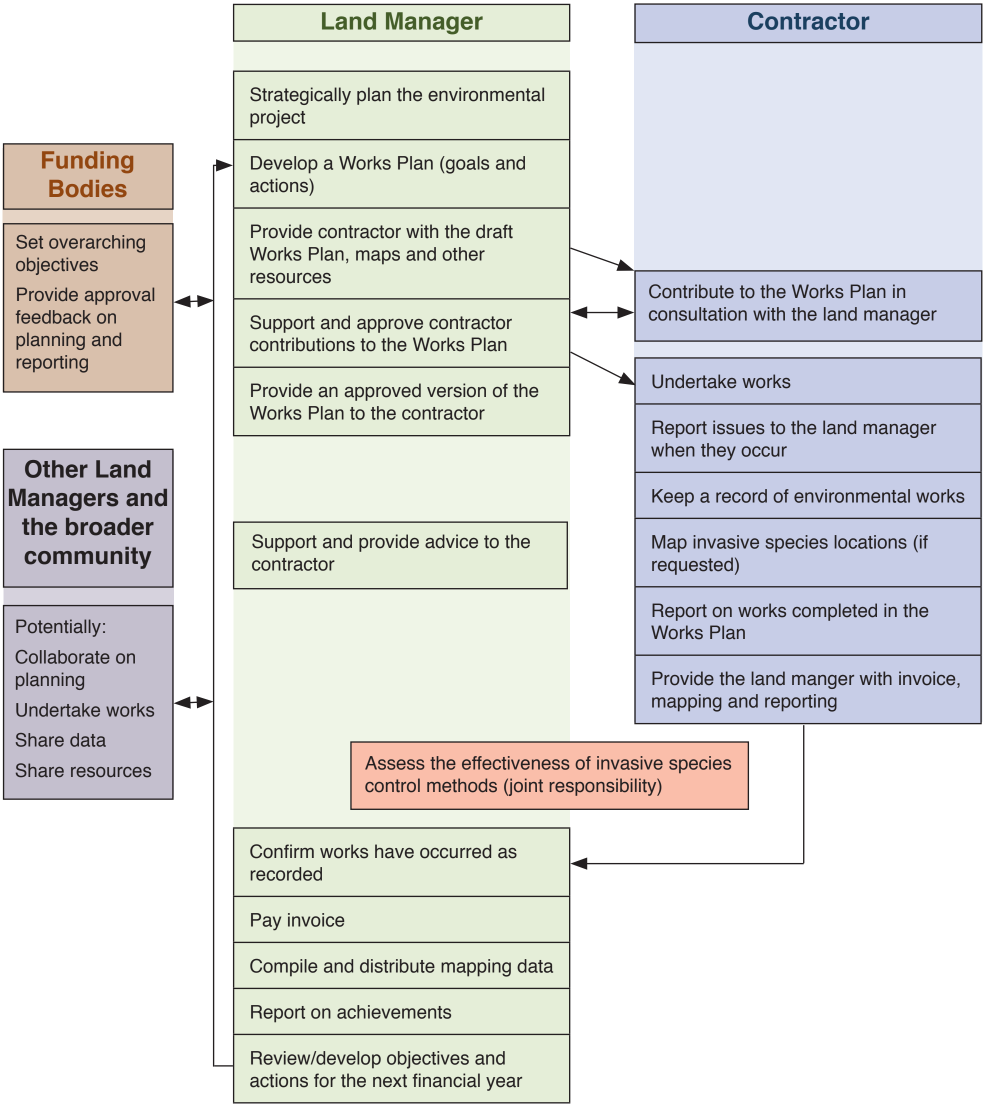
The toolkit targets four different user groups: government agencies, weed contractors, community environmental groups and private landholders. As each group has different skill levels and requirements, the toolkit includes a set of interrelated tools to support each group.

While developing the system the Warrandyte to Kinglake Habitat Corridor Network considered existing state and federal standards, the methods used by network members and the practical input of land managers and works contractors. The tools have been used and reviewed over the length of the project to make sure they are practical for all users.

Environmental Works Toolkit Contents

Manuals and factsheets	Environmental Works Toolkit (overview – this document) Agency guide to running on-ground biodiversity projects (under development) Environmental Works mapping data fields Environmental Works contractor reporting procedure Environmental Works planning, mapping and monitoring – a guide for community groups and private landholders (under development) Weed mapping and monitoring for landholders – fact sheet (under development) Weed Record for Apple Numbers (iPhone, iPad or iPod touch)
Templates	Biodiversity project template (under development) Works plan template – government Works plan template – community (under development)
Data collection tools	Weed mapping and control works recording sheet Rabbit mapping and control works recording sheet Weed data collection – quick reference Rabbit data collection – quick reference Weed Record for Apple Numbers (iPhone, iPad or iPod touch)
Training tools	Presentations Session plans Workshop attendees spreadsheet Copy format Handouts
Additional resources	Nillumbik Shire Council bushland and wetland reserves prioritisation and planning guidelines Nillumbik Shire Council conservation management plan user manual Nillumbik Shire Council conservation management plan template

Following is the environmental works procedure as followed by the toolkit:



This toolkit helps users to make informed and coordinated decisions about invasive species control, as well as other environmental works, at the site level and across the landscape. By linking planning at all levels, the toolkit supports application of biosecurity principles to deliver effective and efficient weed and pest animal control.

Having consistent methods for planning, mapping and reporting for all environmental works is not only useful at an organisational level. It allows government and the community to collectively plan and share results for true landscape-scale management.

For more information or for you copy of the toolkit contact Stacey Warmuth at stacey.warmuth@nillumbik.vic.gov.au or phone 03 9433 3184.

Bridal Creeper Biocontrol Partnership Program (15 years of a community partnership using biocontrol techniques to control bridal creeper on the Bellarine Peninsula and coastline to Breamlea)

Sue Longmore OAM, Coastal Coordinator, Bellarine Catchment Network (1998–2013)

Abstract This paper and presentation is about a fantastic community partnership implementing innovative biocontrol techniques to control bridal creeper on the Bellarine Peninsula. It is a wonderful story of the evolution of the community initiated Bridal Creeper Biocontrol Program which commenced in 1999. A working group partnership of Land Managers and Community Groups from the Bellarine Peninsula have facilitated the release and establishment of leafhopper, leaf beetle and rust fungus sites throughout the Bellarine and along the coast through to Breamlea. Students from Primary, Secondary and Tertiary institutes have been involved in the breed and release programs. The aerial-spraying of rust fungus spore water has continued to be an innovative part of the program developing the release of the rust fungus from a relatively small manual batch process to larger mechanical batching and most recently the trialling of a drone helicopter to release spore water over bridal creeper infestations.

INTRODUCTION

When community and land managers get together it can be a powerful thing. What began as a small trial in 1999 has blossomed into a strong and energetic partnership between a growing number of communities and land managers from Bellarine to Breamlea.

The Bellarine Peninsula is located adjacent to Port Phillip Bay and the Bass Strait coastline, Victoria. A major threat to indigenous vegetation in this coastal area is the invasive introduced plant bridal creeper *Asparagus asparagoides*, listed by the Commonwealth Government as a Weed of National Significance (WoNS) (Thorp and Lynch 2000).

Bridal creeper is a climbing plant that smothers native vegetation, reducing its health and diversity. Berries are produced in spring and the seed is readily spread by birds and other animals. The above ground parts of the plant typically senesce over summer, but the dense mat of tuberous roots growing 10–20 cm below the soil surface, enable the plant to reshoot after autumn rains. The thick, impenetrable tuberous mat prevents natural regeneration of native plants (Australian Weeds Committee 2012).

Community groups and land managers were concerned about the spread of bridal creeper in coastal reserves. Manual removal and use of herbicides were not practical options; the extent of the large infestations made manual removal too labour intensive; and there would have been a high potential for off-target herbicide damage to surrounding native vegetation. A range of biological controls for bridal creeper have been examined (CSIRO 2011). In 1999 the bridal creeper leafhopper *Zygina* sp., a biological control agent, became available for release in Victoria. The leafhopper damages bridal creeper by sucking the photosynthetic cells of the leaf. Facilitated by Swan Bay Integrated Catchment Management Committee (SBICMC), four leafhopper sites were established on the Bellarine Peninsula at reserves managed by Barwon Coast, City of Greater Geelong, Borough of Queenscliff and Parks Victoria, who were all represented on SBICMC.

BRIDAL CREEPER LEAFHOPPER BREED AND RELEASE SCHOOLS AND COMMUNITY PROGRAM

The possibility of involving local schools and communities in a practical biocontrol project working alongside scientists was inviting; and in early 2000 SBICMC (now known as Bellarine Catchment Network) and Bellarine Secondary College assisted research scientists from the Department of Primary Industries (Frankston) to trial the breeding of bridal creeper leafhoppers in a classroom situation and release of the leafhoppers at selected sites on the Bellarine Peninsula. The success of this project led to the beginning of the DPI Bridal Creeper Weed Warriors Program, that was rolled out by DPI through participating schools and community groups across the state of Victoria. By 2008 Bellarine Catchment Network (BCN), together with local primary schools, secondary schools, tertiary institutes, community groups and land managers, had established thirty-eight leafhopper release sites in coastal vegetation on the Bellarine Peninsula and west to Breamlea. This program, facilitated by BCN, has continued each year, with existing sites topped up by further releases. It has been an excellent way to involve community of all ages and increase awareness and stewardship of biodiversity in our coastal reserves.

RELEASE OF BRIDAL CREEPER RUST FUNGUS AND BRIDAL CREEPER LEAF BEETLE

In 2004 bridal creeper rust fungus *Puccinia myrsiphylli* was released for the first time at seven locations on the Bellarine Peninsula and three locations between Barwon Heads and Torquay. Bridal creeper rust fungus is an inert, host specific, non-toxic biological control agent. It is specific only to bridal creeper. It infects the plant's leaf and stem and takes its nutrients to grow from the plant, weakening the plant and its ability to grow and reproduce.

A trial bridal creeper leaf beetle *Crioceris* sp. site at Edwards Point Wildlife Reserve was established in 2005. The leaf beetle damages bridal creeper by stripping the young stems of shoots and leaves. This action impacts bridal creeper by preventing the plant from climbing, and reducing fruit production. The site failed to establish and was not further pursued, as there had also been minimal success at other leaf beetle release sites in Victoria.

By 2008 thirty-six rust fungus release sites had been established on the Bellarine Peninsula coastline and west to Breamlea, through distribution of rust from established sites by our partnership groups. The mass of bridal creeper foliage emerging was observed to be considerably less than in previous years. Leafhopper activity had decreased in many locations, with rust taking over, but there were still pockets where leafhopper activity was high, particularly in the early part of the bridal creeper growing season, from April to June. Despite the success of rust fungus spread, observed in accessible parts of the dune vegetation, we were unable to gauge the extent of rust dispersal by wind into inaccessible areas of dune vegetation, where it had been impossible to gain access from the ground to establish strategic rust release sites.

AERIAL SPRAYING OF RUST FUNGUS SPORE-WATER

In 2006 Bellarine Catchment Network, Barwon Coast, City of Greater Geelong and Friends of Buckley Park formed an informal working party (Bridal Creeper Biocontrol Working Group), collaborating with DPI scientist Greg Lefoe, to trial an innovative rust fungus spore-water aerial spraying program over dense, inaccessible coastal vegetation in Buckley Park Foreshore Reserve and at Thirteenth Beach. The Reserve occupies approximately five kilometres of foreshore and coastal dunes between Point Lonsdale and Ocean Grove and is managed by City of Greater Geelong, on behalf of the Department of Environment and Primary Industries. Thirteenth Beach, located between Barwon Heads and Breamlea is managed by Barwon Coast, on behalf of the Department of Environment and Primary Industries. Thirteenth Beach has areas of dense vegetation and open spaces. Both locations have high biodiversity values.

The intention was to conduct the aerial application during August, the peak time for rust fungus establishment. The project was designed in such a way that the model could be applied to other coastal locations. In July 2006, a ground survey was undertaken by the project partners. Just detectable levels of rust fungus were found within dense vegetation in the proposed trial plot locations. Wonderful that nature was doing her work, but bad news for the controlled experiment which required the trial plots to have no rust fungus present in the initial ground survey so that the presence of rust five weeks after the aerial spraying had occurred would indicate a successful result from the aerial spraying. From a management perspective, however, the project was still a good opportunity to rapidly disperse rust fungus through inaccessible high biodiversity locations.

The aerial application occurred in early September 2006. Rust fungus infected bridal creeper foliage was harvested from well-established rust sites at Coolart on the Mornington Peninsula with a small quantity harvested from some local nursery sites. The foliage was mixed with rain water through a sieve into large 'rubbish bin' vats to produce spore-water, using a rust fungus spore-water technique developed on Kangaroo Island (Overton and Overton 2006). Spore-water was pumped into the tanks of a small helicopter and then sprayed in fine droplets low over the target areas. Five to six weeks later, monitoring of the trial areas found signs of rust fungus establishment.

Over the last six years the rust fungus spore-water aerial spraying program (Figure 1) has been expanded to cover target areas between Bellarine and Breamlea, and techniques have been refined. More land manager and community organisations have joined the working group partnership. Much thought has gone into occupational health and safety, as well as speeding up the batching process. Strong muscles to mix the large vats of rust fungus with rain water have been replaced with custom made batching containers with inbuilt basket

Figure 1. Aerial spore-water application over coastal vegetation in 2012.

sieves that can be mechanically lifted. Each basket can carry 14 × 53 L rubbish bags of wetted bridal creeper foliage for two helicopter tank loads, i.e. 2 × 350 L of spore-water. A larger droplet size is used in the spray unit to increase likelihood of droplets penetrating the canopy and reaching the bridal creeper foliage. A more concentrated batch of rust spores is now mixed.

The key ingredients needed are: slight winds and light rain or moisture in the air; team work, good will and a good amount of flexibility from those involved; staff and community volunteers to harvest large quantities of rust fungus infected bridal creeper foliage up to 48 hours before the target day – any longer and the spores lose their viability; batching equipment at strategic locations; low-flying helicopter; notices in media before the event; letters to residents adjoining the target area; and notices on beach access tracks on the day to inform the community of what's going on.

The program limitations include:

- the amount of rust fungus infected bridal creeper foliage available for harvesting – this has varied from year to year;
- variability of weather conditions – making planning difficult; and
- availability of helicopter, staff and volunteers when optimum weather conditions prevail.

In 2012 a total of 4200 L of spore-water was aerial-sprayed over six target sites at Point Richards Flora and Fauna Reserve, Point Lonsdale Foreshore Reserve, Ocean Grove Foreshore Reserve, Ocean Grove Spit, Thirteenth Beach foreshore and Breamlea foreshore. The minimum spray rate of spore water was 600 L/ha (helicopter spray boom 6 m width; flight distance of 1600 m approximates to a hectare). Costs were $1500 for establishment of helicopter and provision of transfer tanks; and $1.30/L sprayed. Costs were shared between the land managers. The batching equipment was also used in 2012 and 2013 to prepare rust fungus spore-water for on-ground spraying in accessible parts of some of the coastal reserves and along roadsides on the Bellarine Peninsula into which bridal creeper has spread.

AERIAL SPRAYING OF RUST FUNGUS SPORE-WATER USING A DRONE HELICOPTER

Barwon Coast in 2013 trialled the use of a 3.63 m length (including rotor) drone helicopter RMAX Type II G for discrete area spraying of spore water where

Table1. Comparison of piloted helicopter and drone helicopter.

Helicopter	Total tank capacity	Dispersal width	Operation distance
Small helicopter – Heliwork (Australia) piloted helicopter	350 L	6 m spray boom	No restriction
Remote-controlled drone helicopter RMAX Type II G	16 L	3.75 m (using central nozzle only) or up to 7.5 m (using both left and right nozzles)	300 m visual distance from guiding operator

there were vantage points over the control of its use. The trial site was at The Bluff, Barwon Heads. There was a need for the drone to be in visual range of the guiding operator, within 300 m; in particular the take-off and landing point was important for close positioning to the operator. The flight path of the drone was supported by a second person in radio contact with the operator. This person was positioned to provide closer level guidance to the operator of the drone over the uneven vegetation canopy, aiming for 2 m above it. In the operation it was reasonably quick to move locations, loading the drone into the van. The servicing (filling the spray containers for the drone) at the site was easy. Flight time to empty was short so a fair quantity could be sprayed, and batched material was held in a tank on a vehicle with all equipment close together. The spray was set as a direct flow from the tanks, which had a total capacity of 16 L. The down draft of propellers opened up the top of the canopy, with a trickle of spore water falling into the open canopy. The costs were just under $500 for establishment and the day fee for the two personnel and drone was $1000. The positives were the application stream of spore water; the opening of the canopy by the rotor down draft; and the close flying level. Monitoring of rust establishment in these locations will occur in winter 2014. More experimentation of this method is planned for late August/ September 2014.

CONCLUSION

There are obvious benefits for the natural environment stemming from the Bellarine to Breamlea Bridal Creeper Biocontrol Working Group partnership, but just as important are the benefits of camaraderie and experimentation that flow from communities and land managers using their skills and local knowledge alongside each other in such a supportive and appreciative environment.

ACKNOWLEDGEMENTS

Bellarine to Breamlea Bridal Creeper Biocontrol Working Group: Bellarine Catchment Network, Breamlea Coastcare, Friends of Buckley Park, Friends of Edwards Point, Friends of Point Richards, Swan Bay Environment Association, Barwon Coast, City of Greater Geelong, Borough of Queenscliffe, Bellarine Bayside, Parks Victoria, local schools, Gordon TAFE, Bellarine Landcare, CVA; assistance from DPI research scientists and DPI Bridal Creeper Weed Warriors Program.

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The South Gippsland Community Weeds Taskforce

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INTRODUCTION

Back in 2006, the then South Gippsland Landcare Network's Pest Plant and Animal Officer (Martin Chatfield) came up with the idea of forming a community weeds taskforce. The taskforce was a committee formed mainly in response to the local community's concern over changes in State Government weed control policy and the flow-on affects this caused (i.e. reduced resources to tackle established noxious weeds).

The taskforce also sought to:

- identify priorities,
- share data and information,
- foster wider partnerships, and
- educate and inform the wider community and government organisations about weed control priorities and emerging threats.

OWNERSHIP/MEMBERSHIP

The South Gippsland Community Weeds Taskforce consists of 38 individuals representing the following organisations and groups:

1. Various Landcare groups.
2. The South Gippsland Landcare Network Board.
3. Great Southern Rail Trail.
4. Friends of Venus Bay.
5. South Gippsland Shire Council.
6. Department of Environment and Primary Industries (DEPI), (then Department of Primary Industries).
7. West Gippsland Catchment Management Authority.
8. South Gippsland Water.
9. VicRoads.
10. Phillip Island Nature Park.
11. The five Landcare networks across West Gippsland.
12. Parks Victoria.

The taskforce is under the auspices of the South Gippsland Landcare Network. The membership has remained essentially the same as when it began in 2006 however now the scope of the membership base is broader.

The South Gippsland Community Weeds Taskforce meets on a quarterly basis but having lost our funded Pest Plant and Animal Officer position, admin support for our activities via Kate Williams occurs by magic. This funding constraint severely inhibits our ability to do the extension and on-ground works. If it wasn't for the support of the West Gippsland Catchment Management Authority things would be a lot worse. However, lack of funding doesn't stop us from being an effective extension and lobby group for better weed outcomes in South Gippsland.

The taskforce has been in operation now for nearly 9 years, and is still relevant with a greater emphasis on educating and informing the community on the management of pest plant and animals to bring about better weed control outcomes. This is achieved via a four-step approach. We start with carrots, several different types, and only use sticks when we have to.

Step 1. Education. Mail outs, articles in the local papers, non-hostile neighbour contact, letterbox drops, forums, and displays at local events, websites, DEPI and Landcare extension work.

Step 2. Assistance and advice. Can take the form of a friendly neighbour helping another by asking 'do you mind if I spray your weeds?', leading by good example (try and make sure your neighbour notices you doing something about a local weed problem), chemical subsidies, working bees, friendly faces with good advice.

Step 3. Documented approach to landowner regarding weed or pest issues

Step 4. Escalation to DEPI for compliance enforcement. Under the current legislative structure, compliance enforcement is usually expensive, can take years to reach conclusion and in the end may not solve the problem if only 90% of the weeds are removed.

PROJECTS AND INITIATIVES

1. **Community education and awareness**

- Field days and local training including: blackberry and ragwort control field days, fox control field days.
- Rabbit control 'Cook Off' dinner, Weeds to Wonder – Riparian Restoration Field Day.
- Weed information fact sheets.
- South Gippsland Weeds website www.southgippslandweeds.com.au.
- Newspaper articles with a 'Weed of the month' focus.
- Indian myna bird trapping program.
- Weed control calendar.

2. **Working with Government**

- Providing input into DEPI programs.
- Government Minister liaison to highlight the importance of pest plant and animal management in maintain the regions viability.
- Contribution to the noxious weeds review.
- Submit feedback in response to policy changes/developments with the DEPI.
- Assisting with implementing the West Gippsland Catchment Management Authority Invasive Plants and Animals Strategy 2011–2015.
- Actively promoting a land rates charging system which better rewards land owners that do the right thing with the South Gippsland Shire Council.

3. **Legislative changes – our current wish list**

- All nurseries and other plant retailers should be required to taxonomically identify and label the plants they sell.
- Currently, the legislation only requires property owners and managers to eradicate 90% of the weeds on their property – in many cases this is a grossly inadequate number, for example if you leave 10% of a ragwort population you may as well have done nothing, as a relatively small number of plants can generate a huge number of highly viable and mobile seed. The 90% rule also greatly increases the difficulty in prosecuting recalcitrants effectively.
- The current black list approach to banned species condemns us to always being at least one step behind what could be our next major threat. We need to look at a white list approach for approved non-invasive species which can be sold and ban all non-listed species until they have been proven to be non-invasive.
- Currently, it takes far too long and costs far too much to prosecute recalcitrants. There must be a better way.

4. **Resourcing**

- Loss of funding for a full-time Pest Plant and Animals officer severely hobbles our ability to map weed threats new and old, deliver extension work and perform or supervise on-ground works by contractors or volunteers.
- The millions of man-hours and dollars spent on controlling just one species can be wasted if we drop the ball on old threats because we have to divert scarce resources to emerging threats.

IN CONCLUSION

The Community Weeds Taskforce has proven to be a valuable weapon in the small arsenal available to fight our weed wars. It is certainly not the only answer to local weed issues but has become a central player and voice for better weed control. I have the pleasure of representing a group of like-minded, passionate individuals that produce amazing results with minimal resources, but so much more could be achieved. Investment in enterprises like the Community Weeds Taskforce can have massive multiplier effects and we are no exception.

Every time I strap on my back-pack to spray my ragwort and blackberries, I can't help thinking of John Wyndam's book 'The Day of the Triffids' which I read in my misguided youth. There are a few of us on the Community Weeds Taskforce that take sadistic pleasure in killing our Triffids, but my parting message to you today is this:

> '*The Triffids are at the outer perimeter and it's time to switch on the electric fence*'.

A history of fox control on Phillip Island, Victoria

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The red fox (*Vulpes vulpes*) was first observed on Phillip Island, Victoria in the early 1900s and its impact on local wildlife and livestock was recorded soon after. Various methods of control were intermittently conducted, including spotlight shooting, leg-hold trapping and several localised baiting campaigns; however this effort was not suppressing the population. The long-term viability of the last remaining little penguin colony at Summerland Peninsula, which is a major tourism destination, was threatened with up to 300 penguins a year being killed by foxes.

In 2007 Phillip Island Nature Parks (PINP) commissioned a five year Fox Eradication Strategy (McPhee and Bloomfield 2004), which implemented island-wide baiting on private and public land at key times of the year, complemented with leg-hold trapping, spotlighting and den fumigation. In addition to this PINP rangers conducted systematic removal of the weeds African boxthorn (*Lycium ferocissimum*) and blackberry (*Rubus armeniacus*) as these are known to harbour foxes (Marks and Bloomfield 2006).

The initial five years of the program has led to a major knock-down with an estimated 11 individuals (Rout *et al.* In press) remaining (from a carrying capacity of around 400). As foxes are a cryptic species, monitoring fox abundance is difficult, particularly at low densities. Deriving relative abundance indices from a number of different parameters influenced by foxes is considered the best way to measure success of the eradication program. The number of penguins killed by foxes has fallen to extremely low levels (no penguins were found killed by foxes in 2009/2010, a first in 42 years), and other key indicator species such as Cape barren geese and masked lapwings are showing signs of population increment. Comparing indices for bait take, spotlight counts, camera trapping, foot-prints and catch per unit effort (CPUE) over time is another method to gauge the success of the program.

Over the past six years, PINP has received regular visits from staff and detection dogs from the Tasmanian Fox Taskforce (Department of Primary Industries Parks, Water and Environment) to conduct collaborative fox surveys on Phillip Island to locate scats and scent in the landscape. These surveys highlighted the value of detection dogs in locating trace evidence of foxes at low density, and that of trained dogs in locating and destroying the last few foxes on Phillip Island. In 2013 a program review recommended the acquisition of two detection dogs to be permanently based on Phillip Island and deployed by a dedicated Dog Handler. This action is currently being implemented with two dogs scheduled to be working in the field by April 2014.

Future challenges for the program include: preventing fox migration from the mainland (Phillip Island is linked to the mainland by a 700 m long vehicular and pedestrian bridge), preventing reproduction and removing the last few remaining individuals. A recent DNA study by Berry and Kirkwood (2010) has shown that the Phillip Island population of foxes to be distinctive with low genetic diversity and low migration rate (three migrants detected in 480 samples). Another result of the eradication program has been an increase in mesopredators such as feral cats presumably due to reduced competition and direct predation from foxes. PINP destroyed 163 feral cats from farmland and reserves on Phillip Island during 2012/2013 and is now undertaking a public education campaign to educate the community on responsible cat ownership to alleviate the threat to native wildlife posed by cats. A five year integrated feral cat and rabbit management strategy is currently being planned by PINP, Bass Coast Shire Council and other land managers to deal with the changing landscape of vertebrate pests on Phillip Island.

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Walking and working with weeds: performing restoration along the Merri Creek

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In 2012 I began a practice-based visual art research project that considered the question of how print-making and performance could be used to describe the tension between anthropogenic restoration and degradation of the Merri Creek in Melbourne. How could print and performance reflect upon an emotional dialectic between mourning, loss and hope in relation to the creek? And, can visual artistic practices create a platform for community to participate cognitively and physically in this performance? My research investigates how and if transitional spaces of the Merri Creek, such as the struggle between restoration plantings and weed regrowth, can be sites of agency and hope.

These questions came about after I joined the Friends of Merri Creek. I have lived near the creek since moving to Melbourne in 1997. My initial visits to the creek were exploratory. As we investigated our new home, I was filled with sadness as I viewed the rubbish and neglect along the Merri's banks. Over time I began to notice weed mats, fresh plantings and even sometimes groups of people clearing rubbish. My next emotion was one of futility, the creek was so vast and these interventions seemed so small. Years passed and the seemingly insignificant plantings grew into seas of rustling poas and shady groves of acacias and prickly shrubs for little birds. I now look back and realise, that in order to invest in creek restoration, I had needed to see that the work would pay off, that it was hopeful and productive. But needing to see this meant ten years of watching rather than ten years of helping.

In this paper I discuss the processes of my making and will try and connect the work of the citizen volunteer with my work as an artist. In doing so I reflect upon the ongoing and repetitive nature of restoration work especially as it links to the physical and performative nature of my own practice of walking, printing, sewing and wearing.

In March 2013, as part of this project, I walked the length of the Merri Creek. The seven-day walk started at Heathcote Junction, the source of the Merri, and ended at its confluence with the Yarra in Abbotsford. Inspired by Freya Mathews' walk in 2000, recounted in her book: Journey to the Source of the Merri, my walk was a performative artwork and re-enactment of past walks and walkers. Each day I wore a fresh pair of specially made gaiters and pockets. The woolen surface of the gaiters dyed and printed with weeds from the creek, collected mud, seeds, creek water and sweat, tracing my movement downstream. Taking on

Figure 1. Merri Creek Walk: Gaiters, Day 7 unworn (external surface) 2013. Screenprint and dyed: willow bark, artichoke thistle, oxalis. Silk, buttons, hook and eye tape. 48 × 40 cm each. (Photo: R. Mayo).

Figure 2. Merri Creek Walk: Gaiters, Day 7 worn (external surface) 2013 (detail). Screenprint and dyed: willow bark, artichoke thistle, oxalis. Silk, buttons, hook and eye tape, mud. 48 × 40 cm each. (Photo: R. Mayo).

the shape of the walk the gaiters recorded the active space between my body and the creek and, despite their anachronistic design, provided protection from prickles and snakes.

Faced with the ecological challenges of the Merri Creek, I knew that harvesting native species would be problematic, conceptually and in practice, especially when these plants might be newly planted and still becoming established. I also didn't want my work to set a precedent for collecting vulnerable or important species. Consequently weeds are my primary source of dye.

The act of harvesting the weeds, transforming them into dye, preparing the fabric to receive the colour, printing and dyeing the fabric and finally sewing the garments, mirrors the pace and process of restoration work and walking. It is slow, rhythmic and meditative. The seasons and climate dictate when to harvest weeds for dye, just as they influence the optimal times for eradication and control. For example gorse flowers, *Ulex europaeus*, produce a brilliant yellow dye. Harvest is in spring and early summer when the plant is in flower, whilst eradication is best before flowering and seed set. The strength and hue of the dye are altered by rainfall and climate, just as is the energy and enthusiasm of the harvesters. Likewise successful weed control requires experience and expertise as well as manual skills, persistence and local knowledge.

Collecting weeds to make dye and at the same time participating in weed removal set up an interesting tension in my daily practice as an artist and citizen restorer. The plants I co-opt to make my work are the same ones I would like to see disappear from the landscape. On the surface this might seem as if the restoration work would produce a dead end to this aspect of my practice. The reality, however, is that the weeds are not that easy to get rid of, and I will probably always be able to find some gorse somewhere along the creek. Nevertheless, something more intangible is also at play. The tension set up between using the weeds productively while also participating in their eradication allows the garments I make to activate the relationship between citizen restorers, their work, the creek and its history.

The weedy garments worn by citizen restorers act as a costume: like the gaiters, they provide a visual connection between the human and the landscape. The colours derived from the plants return to the creek, and in doing so highlight the restorers' labour. The Friends of Merri Creek wear my garments willingly, the plant-dyed garments visually blending and camouflaging their working bodies into the landscape and unifying the group. Drawing upon the writing of Tim Ingold (2011) the literature around the history of cloth and dyeing (Weiner and Schneider 1989) I suggest the garments and props do more than create a uniform or a quirky event. Rather, the weedy textiles provide a visual and material link between landscape, work and body, heightening the volunteers' conceptual and embodied experience of working at the creek. That is, the need for 'nature' to be attended to by humans in productive ways counteracts the ongoing destruction we pose by simply being.

Most of my gorse collection has occurred near the township of Kalkallo to the north of Melbourne. Running parallel to my project was the Merri Creek

Figures 3 and 4. Friends of Merri Creek gorse removal, Bababi Marning (Cooper St Grassland), November 2013. 'Zeltbahn' Shelter tents and high-vis jackets: dyed and printed with weeds and indigenous plants collected from the Merri Creek, Melbourne. Each quarter tent 190 × 260 cm (h × w). (Photos: David Burrows).

Figure 5. Friends of Merri Creek gorse removal, Bababi Marning (Cooper St Grassland), November 2013. 'Weedy' high-vis jackets, dyed and printed with weeds and indigenous plants collected from the Merri Creek, Melbourne. (Photo: David Burrows).

Management Committee's (MCMC) research project: Mapping of environmental weeds in native grassland. Aerial photograph interpretation and volunteer involvement at Kalkallo Common, an area of Crown land (−37.528171°, 144.953568°).

'This investigation, funded by Caring for Our Country, attempted to interpret Nearmap™ images to map gorse cover at Kalkallo Common grassland before being treated. Gorse's dark colour stands out against grasses – even in aerial photos.

A secondary aim of the investigation was to develop a procedure for training student volunteers to gather the data needed to ground-truth the aerial photomaps. Students from land management courses can provide 'free' labour but it is a challenge to generate accurate assessments with only a brief instruction, while also providing students with a worthwhile learning experience'(MCMC 2014).

This project used volunteer labour from TAFE students in exchange for providing them with tangible field experience. The student comments in the final report revealed the value they placed on leaving the classroom to perform practical activities that make a real a difference in the field. I concur that the physical activity of mapping the weeds, which involved a co-ordinated approach between the volunteers particularly while they pegged out the quadrants on foot using long ropes and GPS positioning, connected the students (even if just for one day) to the site and each other through their collective endeavour. Learning occurred through the practical application of their classroom theory in conjunction with the challenges and problems posed on the day.

Through the production of my weedy textiles and their subsequent reintroduction to their sites of collection, my practice broaches the performance of restoration work, particularly that of volunteer workers. In activating the space between volunteers, experts, weeds, indigenous species, the creek and its surrounding biosphere my practice hopes to open a conversation not only about urban biodiversity, but also about the role humans play in both its maintenance, improvement and degradation.

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Keynote: African boxthorn (*Lycium ferocissimum*) and its pest and other animal relationships in Australia

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Introduction African boxthorn (*Lycium ferocissimum*), is a densely branched, thorny shrub that grows to 5 m. It originates from southern Africa and was introduced to Australia in the early to mid-1800s for use as a hedgerow and windbreak.

It has become one of Australia's most widespread weeds, being spread primarily by seed. Its fruit are consumed by a range of animal species and seed remains viable when excreted.

In Australia, bird, mammal and reptile species are recorded to consume African boxthorn fruit. Many more animal species interact with boxthorn in different ways. The relationships between boxthorn and an array of animal species are diverse.

The success of African boxthorn in invading Australian landscapes is closely related to the species' interactions with native and non-native fauna. Consideration of African boxthorn biology and its interrelationships with animal species is an important component of boxthorn management planning.

ORIGIN AND BIOLOGY

African boxthorn originates from southern Africa. It is widespread in its place of origin, particularly on the coastal belt, being found in the Western Cape, Northern Cape, Free State and Eastern Cape provinces of South Africa, and in Lesotho (Arnold and de Wet 1993, Kriticos *et al.* 2010, Adair 2013).

Boxthorn is a densely branched, thorny shrub that can grow up to 5 m high (but more often 2–3 m), and to a similar width. In wind prone situations such as coastal sites, boxthorn has a quite different habit, being wind-pruned, growing very dense and often relatively short, with its shape determined by the predominant wind direction (Noble and Rose 2013).

African boxthorn has a round berry fruit (5–12 mm diameter) that ripens to an orange-red colour (Figure 1). Each fruit contains 20–70 seeds. Boxthorn is almost always dispersed by seed. Fruits are consumed by a range of animals and seeds remain viable when they have been excreted. In the Canary Islands, seed from

Figure 1. African boxthorn (photo: Colin Wilson).

another *Lycium* (*Lycium intricatum*) has been found to achieve improved germination rates after being excreted by shrikes (*Lanius excubitor*) (Nogales *et al.* 1998).

AFRICAN BOXTHORN IN AUSTRALIA

By the early to mid-1800s, African boxthorn was determined to be an excellent hedgerow and wind-break plant, and was deliberately introduced to and distributed in Australia.

First records of African boxthorn being distributed in Australia appear to be when it was offered on the Tasmanian nursery list in 1845 (Parsons and Cuthbertson 2004).

Mention of boxthorn at Camden Park, New South Wales was recorded by 1850, and by 1857 and 1858 boxthorn was recorded at Hobart and Adelaide Botanic Gardens respectively (Parsons and Cuthbertson 2004).

In Victoria during the late nineteenth century, the planting of boxthorn hedges was a requirement of certain leases in the Western District. However, by 1904 African boxthorn was showing its potential as a weed, and was declared noxious in certain areas of Victoria (Parsons and Cuthbertson 2004).

African boxthorn is now one of Australia's most widespread weeds, being found across a diversity of temperate and sub-tropical Australian landscapes, coastal to semi-arid inland. Figure 2 illustrates the current extent of boxthorn distribution across Australia.

National weed research (Thorpe and Lynch 2000) recorded that African boxthorn was one of only five weed species that were found in at least half of the surveyed regions across Australia. A 2013 research report on coastal weeds (Cousens *et al.* 2013) found that African boxthorn was the species most often cited by natural resource managers as the worst coastal weed in southern Australia (as well as the most commonly managed).

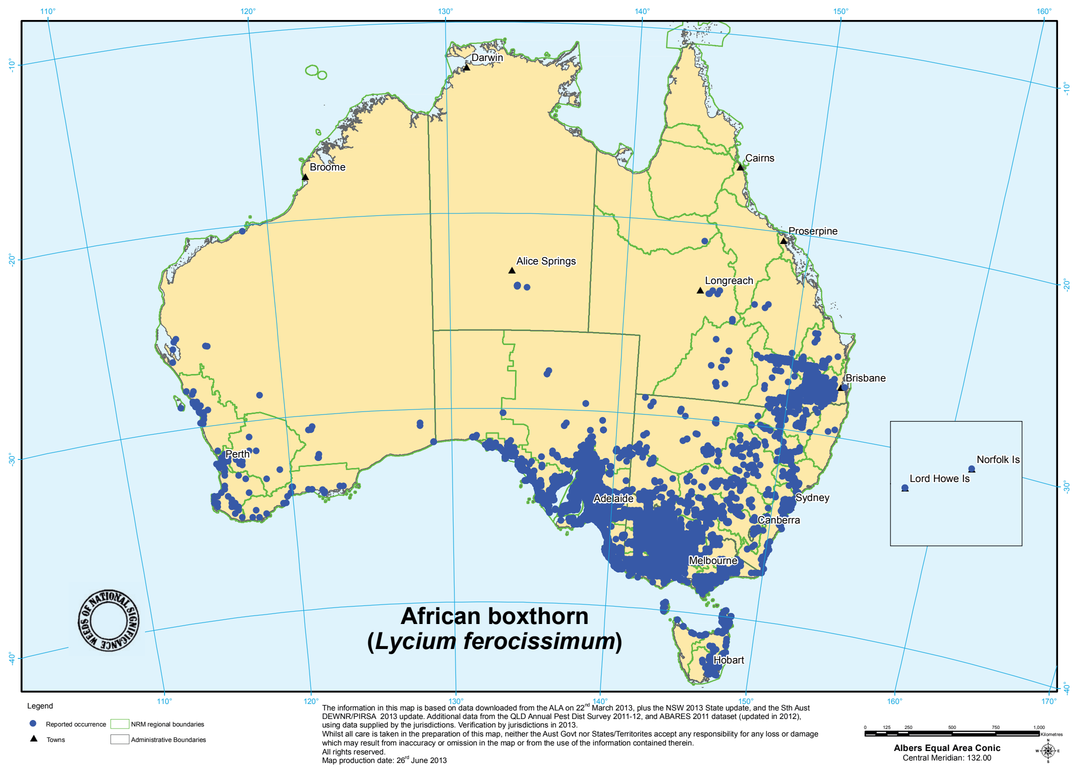

Figure 2. Current distribution of African boxthorn in Australia.

IMPACTS OF AFRICAN BOXTHORN IN AUSTRALIA

African boxthorn negatively impacts a broad range of environments in Australia. Its primary impacts include those upon:

- The natural environment – such as displacing native vegetation, degrading fauna habitat, and directly impacting native fauna (e.g. ensnaring birds).
- Grazing lands – such as reducing access to pasture and water, and harbouring pest animals such as rabbits and foxes.
- Cropping and horticulture – such as hosting key pests and diseases of concern to Australian agriculture (e.g. the potato/tomato psyllid *Bactericera cockerelli* should it enter Australia).

AFRICAN BOXTHORN'S PEST AND OTHER ANIMAL RELATIONSHIPS IN AUSTRALIA

In Australian landscapes African boxthorn has established a complexity of relationships with pest and native animals. Knowledge of these interactions is essential in guiding best practice management of African boxthorn.

At least fifteen species of birds, along with four mammal species and two reptile species are documented for feeding on African boxthorn fruit in Australia (Driessen 2011, Adair 2013, Noble and Rose 2013). These are listed in Table 1. Other species are likely to feed on African boxthorn fruit, but documented records are lacking. For example, the emu (*Dromaius novaehollandiae*), non-native rat species (*Rattus* spp.), and native rat species (e.g. greater stick-nest rat *Leporillus conditor*) are very likely to feed on boxthorn fruit.

Though most of these species documented to feed on boxthorn fruit are native to Australia, it may be that it is the alien animal species that exacerbate the spread of boxthorn (alien/alien synergism). Starlings (*Sturnus vulgaris*) provide a key example detailed later in this paper.

Where boxthorn is used by native animals Where native fauna habitat has been significantly degraded and boxthorn is present, boxthorn can be critical in providing for habitat needs. This is the case for species such as little penguins (*Eudyptula minor*) in places like Low Head (northern Tasmania) where earlier removal of native vegetation has degraded their coastal habitat. Also, critically endangered orange-bellied parrot's (*Neophema chrysogaster*) habitat in coastal Victoria and South Australia includes boxthorn thickets. Where natural habitat has been severely degraded or removed, boxthorn may be providing an alternative, albeit lower quality than local native vegetation.

Table 1. Animal species documented for feeding on African boxthorn fruit in Australia.

Animal type	Species name
Birds	Blackbird (*Turdus merula*)
	Currawong (*Strepera* spp.)
	House sparrow (*Passer domesticus*)
	Little raven (*Corvus mellori*)
	Little wattlebird (*Anthochaera chrysoptera*)
	Mistletoe bird (*Dicaeum hirundinaceum*)
	Pacific gull (*Larus pacificus*)
	Purple-crowned lorikeet (*Glossopsitta porphyrocephala*)
	Red wattlebird (*Anthochaera carunculata*)
	Starling (*Sturnus vulgaris*)
	Silver gull (*Chroicocephalus novaehollandiae*)
	Silvereye (*Zosterops lateralis*)
	Singing honeyeater (*Lichenostomus virescens*)
	Spiny-cheeked honeyeater (*Acanthagenys rufogularis*)
	Yellow-faced honeyeater (*Lichenostomus chrysops*)
Mammals	Eastern barred bandicoot (*Perameles gunnii*)
	Red fox (*Vulpes vulpes*)
	Southern brown bandicoot (*Isoodon obesulus*)
	Tasmanian pademelon (*Thylogale billardierii*)
Reptiles	Cunningham skink (*Egernia cunninghami*)
	Shingleback (*Tiliqua rugosa*)

The nationally endangered southern brown bandicoot (*Isoodon obesulus*) and nationally vulnerable eastern-barred bandicoot (*Perameles gunnii*) are known to consume African boxthorn fruit (Heinsohn 1966, Quin 1985).

In Tasmania and New South Wales, positive correlations have been documented between wombat (*Vombatus ursinus*) burrows and African boxthorn (and blackberry *Rubus* spp. in one case) (Taylor 1993, Roger *et al.* 2007).

The nationally vulnerable greater stick-nest rat (*Leporillus conditor*) is reported to use boxthorn on islands off Ceduna, South Australia for shelter from its primary predator, the barn owl (*Tyto delicuatula)*. The rats have also been observed to feed on boxthorn foliage and when in exceptionally high numbers, they also eat the bark. Greater stick-nest rats also use boxthorn branches in their nest construction (van Weenen 2013).

A scientific expedition to Inner (West) Sister Island, just north of Flinders Island in Bass Strait, recorded Tasmanian pademelons (*Thylogale billardierii*) as being commonly found in boxthorn bushes, having climbed to various heights up to three metres. Pademelons were found to have established routes up through the bushes allowing them access to browse leaves and fruit. This habit of the Tasmanian pademelon appears to be peculiar to this island (Driessen 2011).

It is these types of relationships that make it essential that African boxthorn management works be based on a thorough and holistic planning effort.

Where boxthorn is detrimental to Australian native animals In coastal and island situations African boxthorn impacts on animal species directly (e.g. fatally ensnaring birds), and can significantly alter and interfere with native fauna habitats. For example, on islands off South Australia and Western Australia, boxthorn displaces the native shrub nitre bush (*Nitraria billardieri*) which is used by seals (*Arctocephalus* spp.) for sheltering pups. Boxthorn does not provide the equivalent quality of nursery habitat to nitre bush, leaving pups more vulnerable to predation (Moritz and Kikkawa 1994).

In some small island and coastal dune situations in Australia and New Zealand, boxthorn establishes and is the only woody plant present, changing the vegetation structure (Timmins and Mackenzie 1995, Ziegler and Hopkins 2011). This reduces habitat suitability for native species, and makes the place more hospitable for pest animals like starlings.

Also, African boxthorn root systems are thought to make burrowing more difficult for short-tailed shearwaters (*Puffinus tenuirostris*) (Lawley *et al.* 2005, Noble and Rose 2013). In Bass Strait, the ongoing spread of boxthorn on islands is considered to have the potential to destroy burrowing seabirds' breeding habitat (Brothers *et al.* 2001, Noble and Rose 2013).

The Beagle Islands south of Geraldton in Western Australia provide important habitat for Australian sea lions (*Neophoca cinerea*). African boxthorn grows on East Beagle Island, including at the top of the beach. The large thorns on boxthorn make sea lion access above the beach for pupping difficult and make boxthorn largely unsuitable for shelter purposes also.

African boxthorn's synergistic relationship with the starling in Australia The number of bird species consuming boxthorn fruit in any particular place may influence the number of different microhabitats boxthorn is introduced to, and increase the probability of dispersal to suitable germinations sites (Stanley and Lill 2002).

The presence of starlings appears to be a consistent factor in the comprehensive establishment of boxthorn. For example, with regard to island introductions of African boxthorn in Australia and New Zealand, starlings are recorded as a key factor (Taylor 1968, Harris and McKenny 1999). In Western Australia (WA), where starlings have not yet successfully established, on-ground experience and mapping indicates that African boxthorn has not reached its potential distribution in that state in a similar manner to most other states. The absence of starlings in WA permits greater potential for containment of boxthorn. For example, a recent boxthorn management project by South Coast NRM in Western Australia instigated the use of five kilometre buffer zones around isolated boxthorn infestations (Noble and Rose 2013). This buffer was estimated to exceed the likely movement distance of boxthorn seed with local fauna. Where starlings are present, this is not realistic though with their likely potential to move seed over much more significant distances.

African boxthorn also appears to play a facilitative role for starlings. African boxthorn is tolerant of salanised soil and conditions, and in exposed coastal and island locations in Australia and New Zealand, boxthorn can establish itself as the only woody plant present (Timmins and Mackenzie 1995, Ziegler and Hopkins 2011). The presence of woody plants facilitates roosting habitat for starlings, and in turn, potential for further introduction of boxthorn seed. Experience in Tasmania's Furneaux Group of islands has led volunteer group Friends of Bass Strait Islands to recommend removal of boxthorn plant debris (following cut-stump treatment) by burning. This is essential to remove starling habitat. Starlings will roost even in dead boxthorn plant debris (Ziegler and Hopkins 2011).

In a study of mutualisms and plant invasions, Richardson *et al.* (2000) conclude that facilitative interactions between alien species are widespread and important in accelerating the invasion of natural communities by non-native species. The relationship between starlings and African boxthorn appears to be a strong example of this.

CONCLUSION

African boxthorn is present in a diverse range of ecosystems across Australia. In these situations, it interacts with a broad range of native and non-native animal species. These interactions are complex.

In degraded environments, boxthorn can provide important fallback habitat for some animal species. African boxthorn is frequently a feed source and provider of other forms of habitat for native animal species where native habitat is degraded. However, from a weed management perspective, perhaps the most important animal relationships boxthorn has are those with pest animals. The synergistic relationship that boxthorn has with starlings (and potentially other species), appears to play an important role in determining the potential boxthorn has to occupy a broader range of niches than might otherwise be the case.

Understanding African boxthorn's detrimental and more positive relationships with pest and other animal species is important for land managers managing boxthorn, and critical for planning for successful management of the weed.

Animal relationships with African boxthorn appear to play out in different ways across Australia. It is an important starting point to know the species involved, and the implications they bring for boxthorn management.

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The Keith Turnbull Research Institute: 50 years of pest plant and animal research

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Abstract The Keith Turnbull Research Station, near Frankston, was still under construction as the first scientific and technical staff moved into the newly completed Jean McNamara building in 1964. Fifty years later, the last remaining scientific and technical staff departed to take up residence at the newly completed AgriBio Centre at La Trobe University, Bundoora. In the intervening years the Keith Turnbull Research Institute (or KTRI as it was known for most of its history) made a substantial contribution to pest plant and animal research, development and extension in south eastern Australia. This paper highlights some of KTRI's achievements in invasive species management, and the impact the Institute and its staff had on the social, environmental and economic well-being of Victorians.

A NEW STATE-WIDE FACILITY NAMED

In 1962 the Vermin and Noxious Weeds Destruction Board, part of the Department of Crown Lands and Survey, commenced planning for a new research station. The station was conceived as a centre for research, development and extension (R,D&E), focused on state-wide vermin (pest animals) and noxious weed problems. Frankston, on Victoria's Mornington Peninsula, was chosen as the location for the new facility. Initially called the Keith Turnbull Research Station (KTRS), after the Minister of Lands at the time, the name was later changed to the Keith Turnbull Research Institute, or KTRI as it was known for most of its history.

KTRS was officially opened by the Premier of Victoria, Sir Henry Bolte, on 9th March 1967, although the first staff had already moved in when the Jean McNamara building was completed in 1964. The building was named after Dame McNamara who was a tireless advocate for the release of myxomatosis as a means of rabbit control. The remaining buildings and research facilities were completed between 1964 and 1967, including the triangular-shaped main building which was occupied in 1965 (Vermin and Noxious Weeds Destruction Board n.d.).

Although the KTRI name remained for much of the site's history, there were numerous departmental name changes along the way. From the Department of Crown Lands and Survey, the department changed its name to the Department of Conservation, Forests and Lands, then the Department of Conservation and Environment, the Department of Conservation and Natural Resources, the Department of Natural Resources and Environment, the Department of Primary Industries, and finally the Department of Environment and Primary Industries (DEPI).

ACTIVITIES FROM THE EARLY YEARS

The scope of work at KTRI, and the resources available to do that work, were clearly defined from the beginning. A report from the early 1970s stated that 94 plant species were proclaimed as noxious weeds and eight species were proclaimed as vermin across Victoria – rabbits, foxes, hares, feral pigs, dingoes, wombats, sparrows and starlings. To address these invasive species threats, the Institute employed 15 staff in weed research, 14 staff in vermin research, four extension officers, and eight administration and maintenance staff, including two typists (Vermin and Noxious Weeds Destruction Board n.d.).

Early research projects studied the ecology and control of a range of agricultural weeds, including Paterson's curse, blackberry, horehound, skeleton weed and various thistle species, as well as weeds in non-agricultural situations. Much of the focus of the research into pest animals was on controlling rabbits using fumigation and poisoning techniques, as well as spreading myxomatosis through rabbit populations. A particular strength of the Institute throughout much of its history was the ability to research and develop both chemical and biological control techniques.

In keeping with KTRI's state-wide responsibilities, the four extension officers not only communicated research results directly to the farming community and others, but also to the 160 field officers employed across Victoria by the Vermin and Noxious Weeds Destruction Board. These field officers attended annual two-week training courses held at KTRI, ensuring they kept abreast of the latest tools and techniques for pest plant and animal management. At this time KTRI, in association with the Frankston Technical College, also ran a two-year cadetship program to train new field officers for deployment around the state (Vermin and Noxious Weeds Destruction Board n.d.).

Although primarily funded by State government resources, external funding has been critical to the functioning of KTRI from the outset. Trust funds established from research levies across the agricultural sector supported early research work, including funds from the wool, meat, wheat and dairy industries. Funding from all levels of government and industry continued to support research in later years.

PEST PLANT RESEARCH

Chemical control Developing control techniques for pest plants has been one of the key areas of research at KTRI. As the use of chemicals became more widespread after the Second World War, research became focussed on the most effective herbicides and herbicide formulations, and techniques for application. Trials of different herbicides and herbicide mixtures were undertaken for numerous pest plant species, with the use of a purpose-built track sprayer allowing for precise calibration of spray application rates. The Annual Report for 1976/77 lists herbicide trials for 12 different weed species and also notes that research into Controlled Droplet Application (CDA) was initiated in that year (Vermin and Noxious Weeds Destruction Board 1977). This research incorporated evaluation of hand-held CDA equipment for field use as well as testing the efficacy of CDA across a range of herbicides formulations on different pest plant species.

There was also recognition of the detrimental impacts that chemical control methods can have on non-target organisms and other parts of the ecosystem, with analyses of these impacts dating back to the early days of KTRI. An analysis of herbicide residues in soils was reported in a bulletin published in 1971 and the same bulletin included an article on research into application techniques using thickening agents to reduce spray drift and damage to non-target vegetation (Vermin and Noxious Weeds Destruction Board 1971). In response to concerns from the public about the use of 2,4,5-T, tests on residues in blackberry fruit and in water samples were incorporated into trials, with the results detailed in the 1980 Annual Research Report (Division of Inspection and Vermin and Noxious Weeds Destruction 1980). These trials found that 2,4,5-T residue levels on blackberry fruit were well below levels which would cause human health issues. Low concentrations of herbicide were detected in a waterway for at least 2 km downstream of the spray site, with some herbicide still detectable three days after spraying, but at very low levels.

Weed biological control The Victorian government recognised that herbicides alone would not mitigate the economic and environmental impacts of widespread weeds. A purpose-built quarantine facility enabled the importation and testing of potential new agents (insects, mites, nematodes and pathogenic fungi) for classical biological control programs. As community and industry demand for biological control increased, a larger state-of-the-art quarantine facility was constructed in 1987, followed by extensive insect mass rearing and plant propagation facilities during the 1990s. KTRI became recognised internationally as one of the leading biocontrol agencies in the Southern Hemisphere, providing biological control R,D&E across south eastern Australia, often in collaboration with CSIRO and State agencies. To date, biological control has been implemented in Victoria against 26 weed targets with over 57 biocontrol agent species released (Table 1). Comprehensive information on the history and current status of biological control against Australian weeds is provided in Julien *et al*. (2012).

Unsurprisingly, a strength of KTRI's biological control programs has always been the close involvement of landholders and community groups in the release and monitoring of biocontrol agents. In particular, KTRI developed a school education program in the early 1990s in which primary school students reared and released biocontrol agents for ragwort, boneseed and gorse (Kwong 2002). This successful program, named *Weed Warriors*, was later adopted by the CRC for Weed Management and became a successful national program targeting a range of temperate and tropical weeds (Kwong 2004).

Classical biological control remains the most cost-effective, sustainable management option for weeds where eradication is unfeasible. On average, Australian biological control programs have provided high rates of return on investment, estimated to be in the order of 23:1 and equating to an annual benefit of $95.3M/annum (Page and Lacey 2006).

Some major benefits for agricultural industries across south eastern Australia include successful programs in:

Table 1. Status of agents released or tested for biological control targets in Victoria (E = established, EU = establishment uncertain, N = not established, NR = not released).

Common name	Scientific name	Agent common name	Agent scientific name	Status	Effect on weed
Blackberry	*Rubus fruticosus* L. aggregate	Leaf rust fungus	*Phragmidium violaceum*	E	Defoliates brambles
Boneseed	*Chrysanthemoides monilifera*	Bitou tip moth	*Comostolopsis germana*	N	Feeds on growing tips
		Black boneseed leaf beetle	*Chrysolina scotti*	N	Defoliation
		Blotched boneseed leaf beetle	*Chrysolina picturata*	N	Defoliation
		Painted boneseed leaf beetle	*Chrysolina* sp. B	N	Defoliation
		Lacy-winged seed fly	*Mesoclanis magnipalpis*	N	Destroys developing seed
		Chrysanthemoides leaf roller	*Tortrix* sp.	N	Defoliation
		Boneseed leaf buckle mite	*Aceria* sp.	EU	Leaf buckles
Bridal creeper	*Asparagus asparagoides*	Bridal creeper leaf hopper	*Zygina* sp.	E	Sucks sap
		Bridal creeper rust	*Puccinia myrsiphylli*	E	Attacks stems and leaves
		Bridal creeper leaf beetle	*Crioceris* sp.	EU	Defoliation
Cape Broom	*Genista monspessulana*	Cape broom psyllid	*Arytinnis hakani*	E	Reduces plant growth and flowering
Chilean needle grass	*Nassella neesiana*	Chilean needle grass rust	*Uromyces pencanus*	NR	Infests leaves and stems
Common heliotrope	*Heliotropium europaeum*	Flea beetle	*Longitarsus albineus*	E	Destroys roots
		Rust fungus	*Uromyces heliotropii*	E	Infects leaves and stems
Dock	*Rumex* spp.	Clearwing moth	*Pyropteron doryliformis*	E	Bores into roots
English broom	*Cytisus scoparius*	Twig mining moth	*Leucoptera spartifoliella*	E	Bores into stems
		Seed beetle	*Bruchidius villosus*	E	Destroys developing seeds
		Psyllid	*Arytainilla spartiophila*	EU	Sucks sap
		Gall mite	*Aceria genistae*	E	Reduces plant growth and flowering
		Broom shoot moth	*Agonopterix assimilella*	NR	Destroys shoots
		Broom leaf beetle	*Gonioctena olivacea*	NR	Defoliation

Table 1 continued on next page/…

Table 1 continued. Status of weed biological control agents released in Victoria (E = established, EU = establishment uncertain, N = not established, NR = not released).

Common name	Scientific name	Agent common name	Agent scientific name	Status	Effect on weed
Gorse	*Ulex europaeus*	Seed weevil	*Exapion ulicis*	E	Destroys developing seeds
		Spider Mite	*Tetranychus lintearius*	E	Defoliation
		Gorse thrips	*Sericothrips staphylinus*	E	Reduces plant growth
		Soft shoot moth	*Agonopterix umbellana*	E	Defoliation
		Gorse pod moth	*Cydia succedana*	NR	Destroys seeds
Horehound	*Marrubium vulgare*	Plume moth	*Wheeleria spilodactylus*	E	Defoliation
		Clearwing moth	*Chamaesphecia mysiniformis*	E	Destroys roots
Illyrian and Scotch thistles	*Onopordum illyricum* and *Onopordum acanthium*	Stem boring weevil	*Lixus cardui*	E	Destroys stems
		Seed weevil	*Larinus latus*	E	Destroys developing seed
Paterson's curse	*Echium plantagineum*	Leaf mining moth	*Dialectica scalariella*	E	Mines leaves
		Flea beetle	*Longitarsus echii*	E	Destroys roots
		Crown boring weevil	*Mogulones larvatus*	E	Destroys crown
		Root boring weevil	*Mogulones geographicus*	E	Destroys roots
		Stem boring beetle	*Phytoecia coerulescens*	E	Destroys stems
		Seed beetle	*Meligethes planiusculus*	E	Destroys developing seed
Prickly pear	*Opuntia stricta*	Cochineal scale	*Dactylopius opuntiae*	E	Destroys all aerial parts
Ragwort	*Senecio jacobaea*	Flea beetle	*Longitarsus flavicornis*	E	Destroys roots
		Flea beetle	*Longitarsus jacobaeae*	E	Destroys roots
		Crown boring moth	*Cochylis atricapitana*	E	Bores into crown and stems
		Cinnabar moth	*Tyria jacobaeae*	E	Defoliates plant
		Plume moth	*Platyptilia isodactyla*	E	Bores into crown and stems
Silverleaf nightshade	*Solanum elaeagnifolium*	Leaf-galling nematode	*Ditylenchus phyllobius*	NR	Galls on leaves

Table 1 continued on next page/…

Table 1 continued. Status of weed biological control agents released in Victoria (E = established, EU = establishment uncertain, N = not established, NR = not released).

Common name	Scientific name	Agent common name	Agent scientific name	Status	Effect on weed
Skeleton weed	*Chondrilla juncea*	Gall midge	*Cystiphora schmidti*	E	Galls on leaves and stems
		Gall mite	*Eriophyes chondrillae*	E	Galls the flower buds
		Rust fungus	*Puccinia chondrillina*	E	Infects leaves and stems
Slender thistle	*Carduus pycnocephalus* and *Carduus tenuiflorus*	Rust fungus	*Puccinia cardui-pycnocephali*	E	Infects leaves and stems
Spear thistle	*Cirsium vulgare*	Receptacle weevil	*Rhinocyllus conicus*	E	Destroys developing seeds
		Crown weevil	*Trichosirocalus horridus*	EU	Feeds on rosette and tap root
		Gall fly	*Urophora stylata*	E	Reduces seed production
Spiny emex	*Emex australis*	Stem weevil	*Perapion antiquum*	E	Mines stems
		Fungus	*Phomopsis emecis*	E	Attacks foliage
		Red apion	*Apion miniatum*	N	Attacks stems
	Emex spinosa	Stem weevil	*Lixus cribricollis*	N	Attacks stems
St John's wort	*Hypericum perforatum*	Leaf beetle	*Chrysolina hyperici*	E	Feeds on leaves and shoots
		Leaf beetle	*Chrysolina quadrigemina*	E	Feeds on leaves and shoots
		Aphis	*Aphis chloris*	E	Attacks shoots
		Gall midge	*Zeuxidiplosis giardi*	E	Galls leaves
		Mite	*Aculus hyperici*	E	Reduces plant vigour and seed production
Tutsan	*Hypericum androsaemum*	Rust fungus	*Melampsora hypericorum*	E	Defoliation
Tiger pear	*Opuntia aurantiaca*	Cochineal scale	*Dactylopius austrinus*	E	Destroys all aerial parts
Variegated thistle	*Silybum marianum*	Receptacle weevil	*Rhinocyllus conicus*	E	Destroys developing seed

3. cropping from the reduction in impacts and control costs of skeleton weed – NPV of $1.43 billion (1975 to 2000) and a benefit:cost ratio of 112:1.

1. dairy and beef pasture from the biocontrol of ragwort in Victoria and Tasmania – estimated to provide a benefit:cost ratio of 32:1,
2. meat and wool pasture from the biocontrol of Paterson's curse – the net present value (NPV) is estimated at $1.2 billion, with a benefit:cost ratio of 52:1 since the program commenced 35 years ago, and
3. cropping from the reduction in impacts and control costs of skeleton weed – NPV of $1.43 billion (1975 to 2000) and a benefit:cost ratio of 112:1.

PEST INSECT BIOLOGICAL CONTROL

From the late 1980s, KTRI lead the development of biological control and Integrated Pest Management (IPM) for several pest insects (Table 2). In these programs KTRI staff formed close links with sectors impacted by the pests, and with Australian and overseas researchers. A focus of these programs was to develop safe and effective controls that reduced reliance on broad spectrum insecticides in situations such as forests, orchards, and urban parks and gardens. KTRI staff delivered IPM programs through training workshops, symposia and field days to diverse audiences that included council staff, industry, and home gardeners.

Sirex noctilio is a major pest of *Pinus radiata* plantations, killing around 5 million trees in the three years from 1987 (Bedding 1993 as cited in Waterhouse and Sands 2001). KTRI made an important contribution to the national Sirex biological control program during the late 1980's and early 1990's by rearing and releasing agents, producing extension materials, and monitoring release sites (Andrew 1990, Anon. 1990, F. Gigglioti pers. comm. 2014). The much loved/maligned 'Sirex shed' is a product of this era. The national biological control program was extremely successful; it was estimated that without biological control, Sirex would have caused losses of between $1 billion and $4 billion over 30 years (Bedding 1993 as cited in Waterhouse and Sands 2001).

Two biological control agents for elm leaf beetle, and a parasitoid of European wasps, were also tested

Table 2. Status of agent releases for pest insect classical biological control projects conducted at KTRI (E = established, N = not established, NR = not released).

Common name	Scientific name	Pest status	Agent scientific name	Status	Effect on pest
Codling moth	*Cydia pomonella*	Major pest of apples	*Mastrus ridens*	NR	Parasitises cocooned larvae
Elm leaf beetle	*Xanthogaleruca luteola*	Defoliates European elm trees	*Oomyzus gallerucae*	N	Parasitises eggs
			Erynniopsis antennata	N	Parasitises larvae
European wasp	*Vespula germanica*	Amenity, public health, horticulture and biodiversity impacts	*Sphecophaga vesparum*	N	Ectoparasitoid of prepupae and pupae
English wasp	*Vespula vulgaris*				
Sirex woodwasp	*Sirex noctilio*	Major pest of *Pinus radiata* plantations	*Beddingia* (formerly *Deladenus*) *siricidicola*	E	Sterilises *S. noctilio* females.
			Certonotus tasmaniensis	E[1]	Parasitises larvae
			Ibalia leucospoides	E	Parasitises larvae
			Megarhyssa nortoni	E	Parasitises larvae
			Rhyssa hoferi	N[2]	Parasitises larvae
			Rhyssa persuasoria	N[2]	Parasitises larvae
			Schelettererius cinctipes	E[2]	Parasitises larvae

[1] Native ichneumonid reared to augment naturally occurring populations.
[2] Collett and Elms (2009).

in KTRI's quarantine laboratory and subsequently released. The last pest insect biological control research conducted in KTRI's quarantine laboratory assessed a promising new agent for codling moth. This ongoing project has involved collaboration between KTRI, DEPI Tatura, and New Zealand researchers.

INTEGRATED MANAGEMENT PROGRAMS

By the mid-1990s it was recognised that effective management of invasive species often required an integrated approach. For pest plants, this involved not only the effective use of chemical and biological control options, but also the integration of physical or cultural techniques, such as appropriate crop rotation, pasture management, grazing and fire regimes. Providing ideal conditions for desirable vegetation, whether productive species in agricultural systems or indigenous species in natural ecosystems, is a complementary approach that minimises the impact and invasiveness of pest plants. This has led to the development of research into the rehabilitation and revegetation of native species in natural ecosystems, which reflects a changing emphasis from regarding pest plant control as an end in itself, to viewing pest plant control as one of the important components in the process of restoring native vegetation communities.

This shift in emphasis in managing natural ecosystems builds on the long history within KTRI of expertise in understanding the biology of species. In order to control pest plant species, information is required on its life cycle, growth habit, reproductive strategies, dispersal mechanisms, invasive potential and impact on other species, as well as its susceptibility to control measures. Staff at KTRI have amassed a wealth of data relating to the biology and ecology of pest plant species which occur in different parts of the landscape across Victoria. At a broader scale, this expertise has been applied to gaining a better understanding of non-invasive species and to ecosystems and their functioning.

This broad ecological approach has been a hallmark of KTRI staff endeavours from the earliest days. In a publication from the early 1970s, it is noted that the Section Leader for the Noxious Weeds group was also interested in the effect of the Dartmouth Dam on plants and animals. One of the scientists in the same group listed his research interests as the 'ecology, weed status and control of weeds in non-agricultural situations' (Vermin and Noxious Weeds Destruction Board n.d.). This legacy continues today, as evidenced by a current staff member completing her PhD studying the biology and ecology of the aquatic weed, sagittaria, in preparation for the development of a biological control program for this weed. This complements a recent increase in research focusing on pest plant species in aquatic and riparian situations, which recognises the significant impact these invasive species have on the functioning of healthy waterways, and includes trials testing different revegetation techniques in order to restore native vegetation communities to these areas.

MODELLING AND RISK ASSESSMENT

One KTRI stalwart employed as a young vermin researcher reminisced upon his retirement in 2010 that his 'workstation' in KTRI's early years consisted of a desk, chair, pad of paper and a pencil. Technology, and workstations, have certainly changed in the last fifty years! However the work at KTRI remained focused on research and extension activities for the management of pest plants and animals using the best available knowledge and technology of the day. Access to increasing levels of computing power, for example, has allowed the development of complex models and the application of modelling and mapping tools to address issues in invasive species management. Through understanding the environmental requirements of a species and its dispersal mechanisms, it has been possible to develop predictive maps for its likely occurrence in different places in the landscape, allowing for better targeting of on-ground activities. By modelling the impacts, invasiveness and dispersal mechanisms of a range of invasive species, it is possible to develop a prioritisation process for investment in on-ground management activities which has led to revisions in the noxious weed list. These skills have been developed over more than a decade of research in areas such as weed risk assessment and pest dispersal modelling. The expertise of KTRI staff in this field allowed the development of decision support tools that are used by organisations such as Parks Victoria and Melbourne Water to streamline their resource investment processes for on-ground pest plant management programs.

VERTEBRATE PEST RESEARCH

From its inception, the development of improved vertebrate pest management techniques was a key research area for KTRI, with staff using specifically designed facilities to conduct this research. Much of the early research focused on controlling rabbits, through poisoning and fumigation techniques and through the spread of myxomatosis. Initially the spread of the myxomatosis virus relied on natural mosquito populations (Vermin and Noxious Weeds Destruction Board 1972a), however the European rabbit flea was identified as a more easily controlled vector for the virus and a KTRI program was developed to breed and release large numbers of the flea across the state (Vermin and Noxious Weeds Destruction Board 1977). In 1979/80, more than 355,000 fleas were released, with two thirds of these released in Victoria and the remainder released in NSW, Tasmania and Western Australian (Division of Inspection and Vermin and Noxious Weeds Destruction 1980). The program also assessed the effectiveness of the myxomatosis program, including the development of disease resistance in rabbit populations.

Current research into techniques to control feral cat populations builds on studies such as those undertaken in the late 1970s into feral cat ecology, which investigated their diet, diseases, population dynamics, breeding and movements (Division of Inspection and Vermin and Noxious Weeds Destruction 1980). This study found that in some parts of Victoria such as the Mallee, predation of native mammals and birds by feral cats was lower than expected, and the cats were probably more dependent on rabbits as a food source. Thus it was suggested that rabbit control would be the most effective way to control feral cat populations in these areas.

Amongst the many other projects that have been undertaken to develop effective and humane methods of pest animal control are those that assessed the effectiveness of fertility control in foxes; the impact of 1080 poisoning on non-target species; and the efficacy of browsing repellents in protecting young seedlings from browse damage by rabbits and wallabies (Keith Turnbull Research Institute 1997).

EXTENSION

The extent and breadth of extension activities has changed over time, as have the techniques of delivery, particularly with the increasing use of electronic media. Early annual reports and research bulletins provided updates about research activities and findings for dissemination directly to farmers and to field officers and other interested parties.

One example of a highly practical publication, dating from 1972, is a bulletin entitled 'Recommendations for the Control of Noxious Weeds' (Vermin and Noxious Weeds Destruction Board 1972b) which outlined a brief description of each weed and details of appropriate chemical control including herbicide names and rates for different types of application techniques. Compiled by research and extension officers, this document provided control options for 89 species, some of which are still problematic today including blackberry, hawthorn and serrated tussock. This tradition has continued with the publication of technical reports, Landcare Notes, scientific papers, theses, conference papers and proceedings, books, Weed Management Handbooks, press releases, popular journal articles and other published material that has been widely distributed in hard copy and electronically.

The long-running publication 'Under Control' was a particularly effective means of communicating KTRI research activities, and provided information about other activities in invasive species management from across the state, and sometimes further afield. Detailed information about particular invasive species was included in some issues, providing readers with useful data to help them identify and manage invasive species in their areas.

Although formalised training through cadetships ceased after some years, KTRI continued to play a major role in training, through both formal and informal programs. Staff from the Institute have supervised post-graduate students, given lectures to university and TAFE students, and to industry training courses such as Wise Waterways, an intensive training course run by La Trobe University for waterway managers. Many staff themselves have undertaken post-graduate study, further enhancing their skills and expertise. KTRI staff also contributed to numerous training courses, seminars, workshops and field days for departmental staff and staff from other agencies engaged in invasive species management across the state. These staff also gained significant benefit from databases containing electronic records of spatial data about weed infestations across the state, which were developed and maintained by KTRI staff. Research Staff were also involved in the Environment and Natural Resources Committee parliamentary inquiry into pest plants in Victoria in 1998, as both project staff and through providing technical briefings to the committee.

KTRI provided work experience opportunities for numerous secondary and tertiary students, including many students from the local Frankston area. Several university students were employed through the Cooperative Research Centre (CRC) Summer Student program, which provided benefits to the students and to KTRI projects. The CRC also funded a number of post-graduate students and post-doctoral fellows which provided significant and ongoing benefits to KTRI, beyond the life of the CRC.

As a government institution, KTRI also provided the general public with advice and information. The annual report of 1979/80 states that 2302 enquiries were received in that year, mostly by telephone although 10% were made by letter (Division of Inspection and Vermin and Noxious Weeds Destruction 1980). Topics included proclaimed noxious weeds and vermin animals, non-proclaimed weeds and other plants, animals, insects, chemicals, equipment, literature and cadetship training. General enquiries are now handled by a DEPI Helpline and in the period from January to July 2013, this service received 518 requests for information about pest plant management. Some of these enquiries related to individual weed species, particularly serrated tussock, gorse and Paterson's curse, while others requested advice about plant identification, invasive plant legislation and responsibilities, and training programs now offered by the Department (such as Weedspotters, for example). KTRI also provided information to the general public through Open Days and through visits by school, university and Landcare groups.

THE FUTURE FOR INVASIVE SPECIES RESEARCH

The move of vertebrate pest research to ARI (the Arthur Rylah Institute) in 2005, and the more recent relocation of the remaining science groups to AgriBio, marked a major change in the delivery of invasive species research in Victoria. Invasive species research is no longer conducted in a dedicated pest and weed facility with co-located science, extension and operational staff. Nevertheless, invasive species research at ARI and AgriBio will continue, albeit as part of larger and broader science Institutes. Ensconced in the new AgriBio research facility at La Trobe University, the Weed and Invertebrate Sciences groups will maintain their current focus on weeds of grazing industries, native grasslands, alpine areas and aquatic situations, through continued research on invasive species risk assessment and modelling, and chemical and biological control. However, new opportunities will be explored, including closer ties with universities and the integration of weed and invertebrate sciences with genomics research. This could yield advances in the taxonomy, identification and detection of weed species through rapid gene sequencing technologies to identify DNA profiles or 'fingerprints'. Genetic modification to express introduced genes or silence existing genes can be explored for suppression of herbicide resistance genes, or weedy characteristics, or to increase the efficacy of biocontrol agents or develop biocides. Furthermore, crops can be modified with the aim of enhancing their competitiveness against weeds, for example by manipulating phenology to stimulate germination prior to weed germination (Forster *et al.* 2013). More traditional weed and ecological research techniques could yield insights into the effectiveness of invasive species controls through the study of impacts: how weeds impact the provision of ecosystem services, and what types of control can be used to reduce these impacts. In a world faced with a changing climate, and one in which invasive species are a major driver of biodiversity loss and decreased agricultural productivity, combating these threats will require all the resources of ecologists and geneticists alike (Erlich and Erlich 2013, Pereira *et al.* 2012).

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From Blackberry Control to Landscape Sustainability: next phases for the community-led approach in blackberry management and the Victorian Blackberry Taskforce

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INTRODUCTION

At this point of time, community-led pest management is being mainstreamed across a variety of pest animal and weeds. This is an encouraging shift, where landholders, their communities and Government agencies work together to jointly manage the specific pest and, through this, contribute to sustainable land management at a landscape level. Historically, the enforcement of weed control was seen by the community as the responsibility of the Government. Landholders who had the capacity to do so met their obligations in respect to regionally prohibited and controlled weeds and expected the local Catchment Management Officer to deal with those who didn't via either an enforceable plan or other compliance mechanisms including legal action.

Government intervention was thus relied upon to 'make' people control weeds. When there were reductions in this level of intervention the first reaction from communities was outrage that Government wasn't meeting it's perceived responsibilities. However, the opportunity to design and manage a local community led program, with support, often led to a conclusion that perhaps the previous model hadn't been all that good in achieving a sustained reduction in the level of infestations of regionally controlled (widespread) weeds.

However, the approach is not without its challenges. To be successful, there needs to be a convergence of thinking, approaches and understanding between landholders, agencies and communities, and across pest management. Given this increase in interest in community-led approaches, it is perhaps timely to reflect on some of the lessons from the Victorian Blackberry Taskforce's approach to blackberry management.

THE VICTORIAN BLACKBERRY TASKFORCE AND THE COMMUNITY-LED APPROACH

The Victorian Blackberry Taskforce (VBT) was formed in 1999 to formulate the Victorian Blackberry Strategy (VBS). The objective of the Strategy is to reduce both the spread and impacts of blackberry (*Rubus fruticosus*) by working with state, regional and local natural resource managers, community organisations and private landholders.

The VBT emphasises and encourages community participation and provides support for action. It also provides strategic direction to Government agencies and communities for blackberry control.

To achieve its goals, the VBT uses a community-led approach to blackberry management. The importance of the community-led approach in general, and to blackberry control in particular, has been explored previously (see, for example, Furze *et al.* 2008, Reid *et al.* 2009, Coulston *et al.* 2012) and doesn't need repeating.

However, it's important to remember that the community-led approach is a contested process and different interpretations of 'community-led' result in different outcomes and different impacts. Recognising this allows us to place, at centre stage, the reasoning/rationale for a community led approach. It is this which is the main focus of this paper.

BUILDING RELATIONSHIPS FOR SUSTAINABILITY AND PRODUCTIVITY: INDIVIDUAL LANDHOLDERS, COMMUNITIES AND AGENCIES AS PART OF THE VBT'S COMMUNITY-LED APPROACH

It's perhaps tempting to say the three main stakeholders of the community-led approach – individuals, communities and Government (agencies, policy-makers etc) – are self-evident. In one sense that is the case – these are the significant stakeholders in the VBT's approach and are indeed crucial to a range of other pest-management approaches being rolled out currently. It is within these groups that approaches converge, or need to converge.

Yet in a real sense, this is just the problem to avoid – seeing these stakeholders as obvious. For, whilst we may have agreement on identifying the stakeholders, there can be significant disagreement about what the relationships between these stakeholders should be, and indeed what their roles and responsibilities are, in community-led approaches. In the VBT's experience, if we get these wrong, or treat them as 'given', then there are going to be issues in facilitating and supporting a community-led approach.

For example, as will be seen, the convergence of best practice control with community-led approaches is important, but it is also not without its challenges. Government agencies support this convergence through financial support to community-led groups such as the VBT Partnership Groups, who can employ a project officer to support individual land managers in their efforts. But this also has its challenges in the context of how agencies and individuals interpret the benefits of this convergence.

The relationship between individual landholders and their communities We all know that individuals engage with their communities in different ways. In fact, one of the strengths of a community-led approach is to harness the positive aspects of these forms of engagement and it's this which separates the community-led approach from an approach which just works with individuals. In the VBT's experience, whilst we work with individual landholders/managers, we are very aware that these individuals are part of a wider whole, where individuals engage with others to form communities and networks which are important parts of landscapes and significantly contribute to our success. In other words, thinking needs to move beyond the farm gate and there are a number of different aspects to this.

The first is what might be called the *ripple effect* of an individual landholder's blackberry management actions. As the results of landholders' management actions become obvious, this acts as a catalyst for others to sign up or to take action.

This 'ripple effect' has a number of components to it. One is the visible impacts of the management. People see the decline in blackberry, they see the landholder undertaking works and so on. Ultimately, the property looks different – a change in the landscape and a change in the values people hold relating to that landscape. People view this difference in a number of ways – in terms of productivity for example, or in terms of a 'well-managed farm'. But they can also view this in terms of aesthetics – the farm or the landscape 'looks good'. Irrespective of how individuals see and value the changes, they are then encouraged to take their own management steps. Importantly, there is also evidence from our land managers that once they undertake blackberry management, they are also likely to undertake other management activities, such as soil erosion control or other weed management. Conversations between the project officer and the landholder begin around blackberry, why it's there and a plan to manage it. However over time these conversations broaden, in some cases, to include general land management issues including soil degradation, rabbits and wild dogs. There are extensive opportunities to connect landholders with information about what's happening at a local level and how to implement integrated management plans.

So there is a ripple effect outwards (neighbours and beyond) as well as one inwards (on the farm). Both contribute to more healthy landscapes.

Second is the more informal landholder-to-landholder discussions that take place. People talk about the works they are doing, the support they receive from the blackberry groups and so on. Hence, land management issues become a part of local conversations, local discussions and local priorities. Once this occurs, we again see landscape-level benefits. This works well however, only to the extent that the blackberry groups have legitimacy within the community, and these discussions in turn reinforce the legitimacy of the groups.

There is a third type of effect. As increasing numbers of landholders manage their blackberries, those landholders who fail to manage their land often come under peer or community pressure. This has a dual edge. On the one hand, this type of pressure can encourage blackberry management amongst landholders who haven't prioritised it previously. However, the other side to it is that this type of pressure may not recognise the reasons why individuals aren't managing their blackberry problem – age or financial capacity for example. We have to be very careful that this doesn't, ultimately, lead to negative community relationships forming.

Having legitimate local institutions (in this case, the blackberry groups) is therefore crucial to our approach because it's these that act to ensure a positive relationship between the individual landholder's actions and the 'ripple effect' in whatever form it takes which moves our impacts beyond the farm gate (and into the landscape) and beyond blackberry. Much time and effort goes into supporting a community's desire for a group, and supporting the community to set it up. That is, we support, but we do not 'set up'. That is for the community to do.

The relationship between individual landholders and land management agencies In some ways, local blackberry groups (and also the VBT) play roles in mediating the relationship between Government agencies and local landholders. This is a very important role that our blackberry institutions have, because our community-led approach means there are different roles, responsibilities and expectations to the previous relationships between landholders and agencies. Historically there has been a dependency on compliance to produce an overall level of blackberry management that meets a community standard.

Regular visits to non-compliant land managers by a Catchment Management Officer are resource intensive and don't necessarily lead to good, long term outcomes for blackberry management, in line with community expectations. However as this has been the traditional approach, some communities are unwilling to assume responsibility for leading or support a changed approach.

In a sense, community now drives and government supports. The use of local knowledge to design a local program has resulted in many innovative ideas for engagement with impressive results on ground.

The role of compliance in supporting community action adds value to community efforts after reasonable attempts have been made to engage land managers.

It's obvious that local blackberry groups engage with local landholders to support blackberry management, even though this is the responsibility of landholders. When this works, as it often does, this is based on cooperation – individual landholders cooperating with blackberry groups in blackberry management.

There is however a legislative framework which sits in the background, where agencies are able to use compliance as a management approach. This doesn't always sit well with a community-led approach, as bringing the legislative force of compliance can undo the forms of cooperation that the VBT's approach is based on.

Having said that, however, it's also important to recognise that the reality is not all landholders will engage with their local blackberry groups or manage their blackberries. There are any number of reasons for this (for example, age of landholders, absentee landholders, individuals not accepting their responsibilities etc) and this sets up an important balance which groups have to maintain – supporting those who want to act, but how to deal with those who, for various reasons, don't want to or can't act? It's also crucial to remember that, ultimately, our focus in the VBT is to manage blackberry and to implement the Victorian Strategy. How this is dealt with by local groups, local landholders and agencies highlights the balance that sometimes needs to be struck between cooperation and compliance.

The relationship between communities and land management agencies This relationship is an incredibly important one because, in a sense, it's here that we can see the differences between a community-led approach and previous approaches.

In many ways the 'bottom line' is that a community-led approach requires changes to thinking and changes to actions and activities – by Government agencies and their staff, by local communities, and by individual landholders. This represents the continuum which was introduced in a previous paper (Coulston *et al*. 2012) where one end represents local involvement because it makes things easier for agencies (they shift their responsibilities) and the other end represents community involvement because it's an ethical thing to have happen (representing the rights of local communities and landholders to be partners in the management of their landscapes and have shared responsibilities over this).

When we think about this in terms of convergence of approaches which we now have, the VBT's challenge was to work with communities, individual landholders and Government in ways which supported communities and individuals, ensured legislative requirements were met, and provided a mechanism for 'good faith' discussions and interactions. It's only been through that foundation that the rippling out of the blackberry groups' impacts on landscape sustainability has been possible.

CONVERGING APPROACHES FOR MANAGEMENT: SOME LESSONS FOR PEST MANAGEMENT AND LANDSCAPE SUSTAINABILITY

The community-led approach to blackberry management has evolved (as the VBT has) over a period of many years. As mentioned earlier, technical approaches have converged with community-led assessments of needs and with individual land managers' activities. There have been some important lessons which have emerged and which are important to consider as the approach takes on more of a landscape –level focus and is rolled out across other pests and into other parts of Victoria.

There is a significant difference between being community-led and previous approaches The VBT has been very careful in the ways it has been both facilitating and supporting local blackberry groups. A central plank to this is a partnership approach, based on cooperative systems to support landholders to manage their blackberries. Here, the 'given' is that groups will partner with landholders and land managers, private and public, and will be working together in the sense of sharing a common desire to manage blackberries. Each blackberry group however has flexibility in how best to achieve this 'given' in ways which suit local conditions and local priorities. For example, priorities and conditions in the Upper Murray will be different to those in Gippsland or on the coast. This means blackberry groups have flexibility to network with other local groups and through that further contribute to, or support, landscape-level sustainability. In a sense, what this means is the VBT's approach moves beyond blackberry itself.

An important part of this in the early days of the approach was managing expectations. Landholders had expectations that Governments had responsibilities to ensure blackberry control was carried out. Agencies had expectations that individual landholders should 'comply' with legislative frameworks.

But having achieved this, the VBT and the local blackberry groups contribute to a community-led process which is becoming increasingly engaged with landscape-level changes – either through blackberry management or beyond blackberries as the ripple effect discussed above takes hold. As the approach is rolled out across other pests, there is a very real potential for integrating ideas, approaches and actions across the landscape, further contributing to landscape level sustainability. It may be very interesting to think about how this might be able to be achieved.

Receptive agencies support receptive communities. Receptive communities support receptive agencies The VBT's experience highlights the importance of *shared* shifts in thinking. There needs to be a shared understanding of what the approach is doing and why it's doing it, as well as a shared set of expectations related to roles and responsibilities.

In the VBT's experience, establishing these shared expectations and understandings amongst the three stakeholder groups is crucial to facilitating community-led approaches. This is a highly negotiated process – community-led approaches do involve shifts in thinking by agencies and on-ground staff, shifts in expectations by local landholders and the facilitation of local groups/institutions (or changes to existing groups).

Additionally, communities need to be supported (financially in particular) to take on these kinds of responsibilities, individual landholders need to understand where the benefits are going to accrue (and why) and the community institutions need on-going support from agencies to achieve what they need to achieve. The issue of 'benefit' is an important one that needs thoughtful analysis. There are economic benefits certainly, not only in terms of improved productivity but in terms of Government spending. But there are also those other benefits mentioned above – ecological benefits, socio-cultural benefits, landscape benefits for example.

Engaging people who then become drivers of change It should be obvious, but for the approach to work people need to be engaged. We highlight this because whilst it should be obvious, it isn't always obvious. 'Engagement' is a surprisingly contested concept – one that covers a spectrum of thinking that engagement occurs because someone comes to a meeting, to 'engaging' through distributing newsletters and strategic plans, to identifying and supporting 'champions'. All these, and others, have their strengths and their limitations. The important point is to make sure that engagement strategies make sense in terms of roles, responsibilities and expectations, and in terms of the actual process itself.

Ultimately, engagement means people are *actively* engaged in the approach, not treated as passive recipients of technical information and actions. This convergence of the technical aspects to management and the multiple social, economic and political dynamics of community-led approaches are crucial, and can be difficult to achieve in the short-term. Understanding the different ways and reasons people engage (economic reasons? wanting to be seen as a 'good farmer' [and if so, what does 'good farmer' mean]? wanting to leave a good farm for the next generation?) is essential to this.

The approach is process-driven, with its strengths and its limitations Perhaps one of the most important things to remember is that a community-led approach is process-driven. It's not a 'one-size fits all' blueprint but a complex and often slow series of negotiations, developed shared understandings and expectations and closely-aligned means/ends.

Perhaps we shouldn't think of a 'community pest management model'. We should think of 'approaches to community-engagement for pest management'. If we think of things this way, it's perhaps not too big a stretch to envisage an integrated network of community-led approaches spread across a landscape, contributing to sustainability and community-resilience.

CONCLUSION

The VBT's community-led approach has been evolving for some ten years. It hasn't been an 'overnight success' but the outcome of commitment to the approach by landholders, communities and individuals in relevant Government agencies. It's the result of negotiations, of 'good faith' actions and of mistakes which we have all learned from. It has been, and continues to be, a highly iterative process.

A challenge? Yes. Worth it? Most definitely.

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Victorian Serrated Tussock Working Party
Building the capacity of communities to manage serrated tussock

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Established in 1995 in response to community concern about the rapid spread of serrated tussock across the landscape to Melbourne's west, the Victorian Serrated Tussock Working Party (VSTWP) is the lead organisation for serrated tussock management in the State. The VSTWP works to achieve its vision to '*control the spread of serrated tussock in Victoria to reduce the impacts on the economy, society and the environment*' (VSTWP Strategy 2012).

The VSTWP was instrumental in the development of the first strategy to manage serrated tussock 'A Strategy for the Management of Serrated Tussock in Victoria', and oversaw its implementation. This document was superseded by 'Intensifying the Attack on Serrated Tussock 2005–2010' and more recently by the current strategy 'Victorian Serrated Tussock Strategy 2012–2017'. The VSTWP is responsible for implementing the Strategy's objectives, and this is realised through:

- Developing partnerships with government, industry, Landcare and other stakeholders.
- Advising State and local government agencies on the impact and management of serrated tussock.
- Advocating community-led action, raising awareness through education and extension activities, and encouraging communities to voluntarily manage serrated tussock.

The VSTWP is one of three Community Pest Management Groups (CPMGs) established in Victoria to promote and coordinate the voluntary management of the widespread established weed species: blackberry, gorse and serrated tussock. These groups are community-led, with the individual committees comprising concerned community members who volunteer their time to campaign and raise awareness of their respective weed.

CPMGs are primarily funded by the Department of Environment and Primary Industries (DEPI). This financial assistance enables the CPMGs to coordinate community weed management programs that assist affected communities to strategically manage infestations, while also complementing pest plant management programs administered and delivered by DEPI.

SERRATED TUSSOCK IN VICTORIA

The 'core' of Victoria's serrated tussock infestation is located to the west of Melbourne in the catchments of Port Phillip and Western Port, and Corangamite. The area on the perimeter of the core is defined by DEPI as the serrated tussock line of containment, commonly referred to as the 'containment line' (see Figure 1).

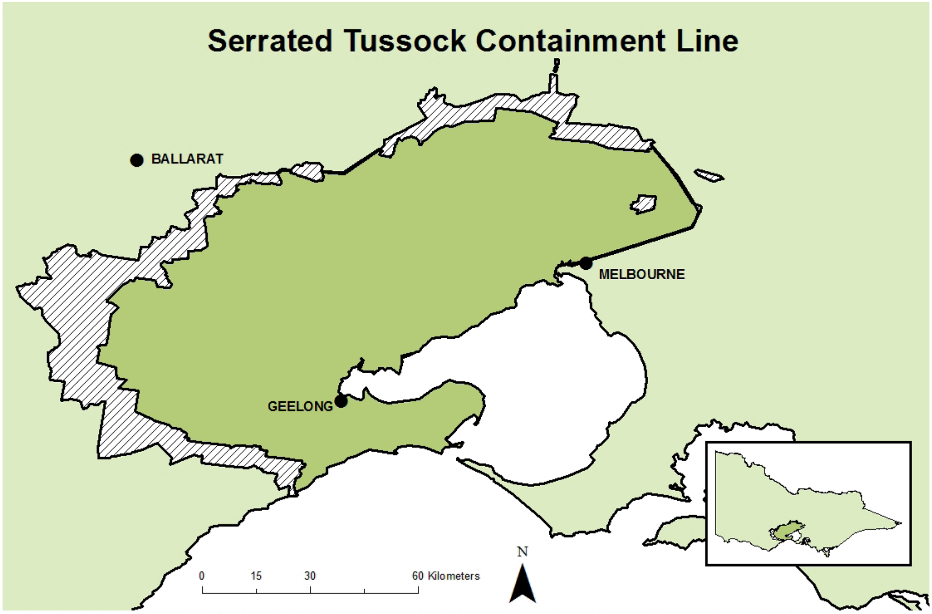
DEPI manage infestations of serrated tussock in priority areas within the borders of the containment line, as well as isolated infestations scattered across the State, through enforcement projects as part of their State-wide serrated tussock containment program.

To support DEPI's containment program and achieve the objectives of the Victorian Serrated Tussock Strategy 2012–2017, the VSTWP coordinates a targeted extension program in communities located along the containment line. Selectively focusing the program in this area produces greater public and long-term benefits by reducing existing infestations, and helps to prevent the spread of serrated tussock into un-infested areas.

The targeted extension program is pursuant to the principles and objectives of extension; providing information, advice and ideas to individuals or communities, thereby increasing their knowledge, capacity and confidence to independently tackle problems, while also influencing decision making and generating practice change.

The program is community based and encourages collective action over a wide area by equipping landholders with the required skills and knowhow to manage serrated tussock infestation for the long-term. The targeted extension program endorses the community-led approach to weed management by increasing landholder capacity and encouraging communities to voluntarily manage serrated tussock, in turn reducing their reliance on government intervention.

Figure 1.



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Areas of scattered serrated tussock infestations.

Serrated Tussock Containment Line.

Core area of serrated tussock infestations.

The areas identified for targeted extension are determined in consultation with DEPI. Defining the boundary of an area is informal and often influenced by the proximity of main roads, waterways or council boundaries. It is an expectation that extension and community engagement activities in a target area are completed within a six month timeframe, therefore when determining the size of an area factors such as landform, land use, and property size need to be considered. As a result, target areas may range between 3000 to 20,000 hectares in size, and contain anywhere from 150 to 250 parcels of land. Properties less than one hectare in size, located within townships, are not directly targeted but if serrated tussock is observed on such a property the landholder will be engaged.

The targeted extension program was established in 2010, since its inception extension activities have been completed in five adjoining target areas located to the west of Geelong, these neighbouring areas form a band on the western edge of the containment line. An area has also been completed to Melbourne's north. It is expected that a further five target areas will be completed by 2015.

PROGRAM DELIVERY

The VSTWP contracts Extension Officers to deliver free education and extension services, their main role being to engage with all landholders in a target area, providing information and management advice on serrated tussock while advocating the benefits of coordinated community action.

The program works by focussing on a target area for a period of 4–6 months, during this time the Extension Officer promotes the program via letter drops, media articles and information sessions. Distributing information and extension material on mass and conducting local information sessions has proven to be a successful means of relaying the message round a community that a VSTWP serrated tussock Extension Officer is working in the area.

While working in a target area, Extension Officers also engage with local councils and Landcare and, where appropriate, promote relevant natural resource management incentive projects such as Melbourne Water's Stream Frontage Management Program

Drawing on their knowledge and experience, Extension Officers educate landholders on serrated tussock identification and provide advice on best practice and integrated management techniques. This is reinforced by take home educational material, including identification and best practice management guides. In addition, landholders within a target area are offered the opportunity to have an Extension Officer assess their property for serrated tussock, providing tailored on-farm management advice.

When a property is found to contain serrated tussock, the landholder is shown the location of the plants and provided advice on the best method of treatment for the situation, a property map is also provided indicating the location of the infestation/s. If a property is identified as having a large infestation the Extension Officer also develops a management plan, to assist the landholder with the long-term management. Extension Officers regularly re-engage with these landholders, to provide encouragement and ensure infestations continue to be actively managed.

A key feature of the program is the one-on-one extension, encouragingly many landholders visited by Extension Officers are already aware of serrated tussock and actively managing their infestations. However the intrinsic value of the program becomes evident when a landholder with no prior knowledge of serrated tussock or management experience, is provided the skills to identify, manage and prevent the establishment of new plants.

As representatives of the VSTWP, the Extension Officers are consistently well received by landholders and their proven skills in identification and knowledge of management techniques heightens community acceptance. Landholder uptake and participation in the program has been high across all target areas, with participants responding positively to the service provided by the VSTWP.

As a result of its success within the core area, the VSTWP is considering expanding the program to support communities outside of the Port Phillip and Corangamite catchment where outlying serrated tussock infestations occur.

CONCLUSION

While the targeted extension program is somewhat labour intensive, it has shown to be a successful method in facilitating the voluntary management of serrated tussock over large areas. On average 93% of serrated tussock infestations are voluntarily treated by landholders at the time of extension activities.

A challenge for the program is ensuring the momentum of landholders and communities in target areas is sustained. In an attempt to address this concern, in 2013 landholders in completed target areas were sent a letter reminding them of the approaching season and of their obligation to manage serrated tussock. These letters were received positively and a number of landholders requested a re-visit from an Extension Officer for additional advice. However, to formally measure the long-term effectiveness of the extension program a comprehensive evaluation process needs to be undertaken.

The VSTWP recognises that this program is not going to eradicate serrated tussock from an area, it is however recognised as an important step to increasing landholder awareness of the far reaching effects of serrated tussock, creating ownership and encouraging voluntary community-led action.

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Tolerance of native grassland species to broadacre agricultural herbicides – glasshouse screening trial

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INTRODUCTION

The Victorian Government intends to reserve 15,000 hectares of land, 'The Western Grassland Reserve' (WGR) to protect native grasslands in Melbourne's west as a trade-off for the expansion of Melbourne's Urban Growth Boundary (UGB). The WGR covers two large areas around Mt Cottrell and Little River south west of Werribee. The primary aim of the WGR will be nature conservation, in line with international standards for protected areas (Dudley 2008).The WGR is composed of a mixture of 'vegetation states' ranging from high quality grasslands through to environmentally poor fertilized pastures and cropping areas. This land is principally composed of acquired farmland and land left vacant from previous urban growth speculation.

Weed management using herbicides is of fundamental importance to maintaining and restoring biodiversity in the WGR. It is vital to understand the likely off-target effects of herbicides used at sites with different native species compositions. This project quantified the effects of broadleaf and grass selective as well as knockdown herbicides to kill or suppress target weeds, as well as their effect on native species. The native species selected were species likely to occur in the Western Grassland Reserves, from a range of plant families likely to represent a wide range of physiological responses to herbicide.

ABSTRACT

Management of weeds in native pastures nd grasslands of the Victorian Volcanic Plain is difficult due to the similarity of native species to certain weeds species, due to the fact that many weeds come from similar ecosystems overseas, and many of the weeds are in the same families as the native species (Poaceae, Asteraceae, Plantaginaceae). Most existing strategies rely on a high labour input to undertake the task, either by chemical application or manual weed removal. Given the density of weeds in certain areas of the Victorian Volcanic Plain, high labour strategies are cost prohibitive.

The effect of commonly-used herbicides on many native grass and herb species is unknown for the Victorian Volcanic Plain, prohibiting or discourageing the use of potentially powerful herbicides in many contexts.

This project investigated the application of six broadacre herbicides at two rates, on a range of native grasses and herbs, or susceptible weeds. The trials were undertaken in glasshouse conditions and indicate that certain native plant species can tolerate applications of broadacre herbicides. These findings provide a new direction/option for management of weeds in native grasslands if permits or registrations for sale for use can be obtained.

METHOD

A range of native grasses and herbs, together with known weeds (Table 1) were re-potted as single plants into 6 inch pots and acclimatised in a glasshouse prior to being randomised into treatment groups. Each treatment group consisted of one of each species and was allocated to a randomly assigned bench in the glasshouse. The trial design was a 3 replicate, randomised block design.

After acclimatisation, each treatment group was sprayed with the allocated herbicide treatment (Table 2) using a laboratory track sprayer operating at 3 bar and 7.39 km/hr delivering a water rate of 100 L/ha (August 2012). The broadleaf selective herbicides were applied at kill rates. The grass selective herbicide rates were chosen in consultation with agronomists and producer workshops (MLA 2011).

Plant damage scores (0–9; 0 = healthy, 9 = dead) were recorded on a weekly basis, followed by

Table 1. Native plant and weed species used in the experiment.

Species no.	Species name	Species no.	Species name
1	*Podolepis* sp. 1 (Asteraceae)	14	*Eryngium ovinum* (Apiaceae)
2	*Chrysocephalum* sp. 1 (Asteraceae)	15	*Calocephalus citreus* (Asteraceae)
3	*Caesia calliantha* (Liliaceae)	16	*Linum marginale* (Linaceae)
4	*Nassella trichotoma* (Poaceae, C3)	17	*Themeda triandra* (Poaceae, C4)
5	*Ptilotis spathulatus* (Amaranthaceae)	18	*Austrostipa bigeniculata* (Poaceae, C3)
6	*Nassella hyalina* (Poaceae)	19	*Galenia pubescens* (Aizoaceae)
7	*Leptorhynchus squamatus* (Asteraceae)	20	*Convolvulus angustissimus* (Convolvulaceae)
8	*Oxalis perennans s.l.* (Oxalidaceae)	21	*Wahlenbergia communis* (Campanulaceae)
9	*Rytidosperma duttonianum* (Poaceae, C3)	22	*Geranium retrorsum s.l.* (Geraniaceae)
10	*Cynara cardunculus* L. (Asteraceae)	23	*Rytidosperma caespitosum* (Poaceae, C3)
11	*Bothriochloa macra* (Poaceae, C4)	24	*Asperula conferta* (Rubiaceae)
12	*Dianella admixta* (Liliaceae)	25	*Vittadinia muelleri* (Asteraceae)
13	*Plantago gaudichaudii* (Plantaginaceae)	26	*Brachyscome dentata* (Asteraceae)

Table 2. Herbicides, wetters and rates used in the experiment.

Treatment	Trade name	Herbicide actives	Rate active 1	Rate active 2	Wetters	Wetter rate
1	Roundup ATTACK	Glyphosate 570 g	0.19 L/ha			
2	Roundup ATTACK	Glyphosate 570 g	0.28 L/ha			
3	Kenock	Flupropanate 745 g/L	0.25 L/ha			
4	Kenock	Flupropanate 745 g/L	0.50 L/ha			
5	BrushOff + Thistle Killem 750	Metsulfuron methyl 600 g/kg + MCPA amine 750 g/L	5.00 g/ha	1 L/ha	BS1000	200 mL/100 L
6	BrushOff + Thistle Killem 750	Metsurfuron methyl 600 g/kg + MCPA amine 750 g/L	15.00 g/ha	1 L/ha	BS1000	200 mL/100 L
7	Lontrel 600 + Thistle Killem 750	Clopyralid 600 g/L + MCPA amine 750 g/L	0.15 L/ha	1 L/ha		
8	Lontrel 600 + Thistle Killem 750	Clopyralid 600 g/L + MCPA amine 750 g/L	0.25 L/ha	1 L/ha		
9	Grazon Extra	Triclopyr 300 g/L, Picloram 100 g/L, Aminopyralid 8 g/L	2.00 L/ha		Pulse	0.10% v/v
10	Grazon Extra	Triclopyr 300 g/L, Picloram 100 g/L, Aminopyralid 8 g/L	3.00 L/ha		Pulse	0.10% v/v
11	Verdict 520	Haloxyfop-R as methyl (520 g/L)	0.20 L/ha		Hasten	1% v/v
12	Verdict 520	Haloxyfop-R as methyl (520 g/L)	0.40 L/ha		Hasten	1% v/v
13	Control	None	–	–		–

fortnightly randomisation of pots within treatment groups, and also randomisation of benches within each block.

Data was statistically analysed using Genstat. Scores are restricted to be between 0 and 9, and this implies that the actual variation when means are close to 0 or 9 are smaller than when the means are half way. Thus the data was angularly transformed such that the magnitude of the residual variation about the mean was similar for all means.

RESULTS (SEE TABLE 3)

Broadleaf selective herbicides – metsulfuron methyl + MCPA, clopyralid + MCPA, triclopyr + picloram + aminopyralid All selected rates and mixtures had significant effects on one or more of the target weed species. The chemicals also had significant impacts on other native monocots and dicots, although the common native grasses were generally not affected.

Glyphosate and grass selective herbicides – Haloxyfop-R, flupropanate Only Haloxyfop-R significantly affected the target weed species. Verdict significantly affected most of the common native grasses, except spear grass and wallaby grass. The low rate flupropanate and glyphosate treatments did not significantly affect any of the native monocot or dicot species, or the target weeds.

DISCUSSION

Despite many of the broadleaf herbicide mixtures affecting other native dicot species, only one of the mixtures (clopyralid + MCPA), affected one of the common native grass species, *Bothriochloa* sp. The use of these broadleaf selective herbicides as a boom spray application may be a more cost effective option than hand spraying weeds in paddocks that lack native dicot species, and contain common native grasses other than *Bothriochloa* sp. (if using clopyralid + MCPA).

Glyphosate was used at Spraytop rates known to suppress *Nassella* spp. seed production (Gaur *et al.* 2005). As expected, the target weed and non-target species, were not significantly affected by the treatment – including all of the native species. This treatment is thus promising as a 'holding technique' to suppress *Nassella* spp. weed seed production without significantly affecting the listed native species.

Flupropanate was used at rates that have shown to be less damaging to native grasses (Grech and McLaren 2011). The rate selected was believed to be ineffective on the target weeds for several reasons including heavy overhead irrigation in the glasshouse causing the chemical to leach through the loamy soil profile, as well as stress free growing conditions. For these reasons the use of low rate flupropanate on the listed native species is not conclusive and needs to be tested in the field.

Given the range of native species tested in the experiment, and their respective growing seasons (C3 vs C4), consideration needs to be given to the timing of spray application to minimise damage to non-target species. As all species were sprayed at the same time for this experiment, certain species may not have been actively growing and thus uptake and translocation of the herbicide may be impacted. Tolerance may be due to lack of uptake, translocation, target site or metabolic changes. For these reasons, the chemicals need to be tested on the species in the field.

CONCLUSION

Several herbicide options have been identified that may reduce the cost of undertaking control works for *Nassella* spp. grass, and broadleaf weed control in areas with native species. The use of spraytopping with glyphosate to reduce weed seed production has also been identified as a 'holding technique' for weed control in paddocks with native species. This trial had certain limitations that would be overcome if the chemicals were tested on the species in the field. Perhaps not surprisingly, however, there is no single herbicide which can be used safely against a broad background of native species

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Table 3. Angular backtransformed means of plant damage scores (0-9; 0=healthy, 9=dead) 119 days after treatment. P values are for comparison only to the control + ineffective treatments column (* = .05, ** = .01, *** = .001).

Species	Control + Ineffective treatments (glyphosate and flupropanate)	Verdict 520	Brush Off + MCPA	Lontrel + MCPA	Grazon Extra
Grass weeds					
Nassella trichotoma	0.8	8.1***	0.7	1.9	5.4*
Nassella hyalina	0.4	5.2***	0.2	1.5	0.5
Broadleaf weeds					
Cynara cardunculus L.	0.6	0.4	3.5*	6.6***	9.0***
Galenia pubescens	3.2	2.1	2.7	1.4	9.0***
Common native grasses					
Rytidosperma duttonianum	0.8	1.9	2.2	1.5	2.8
Bothriochloa	0.5	6.0***	0.8	4.6**	0.7
Themeda triandra	2.6	7.7***	1.7	1.1	3.4
Stipa	0.9	1.9	1.7	2.4	2.3
Rytidosperma caespitosum	1.4	7.4**	2.2	2.6	2.4
Other monocots					
Caesia calliantha	0.2	0.1	8.4***	0.4	0.3
Ptilotis spathulatus	1.4	0.3	2.4	5.8**	8.8***
Dianella admixta	0.6	0.3	3.2	0.0	6.9***
Dicots					
Podolepis	0.6	1.1	5.7***	0.3	0.8
Chrysocephalum	2.8	1.1	4.1	1.6	3.4
Leptorhynchus	3.0	2.0	6.8*	7.2**	8.6***
Oxalis perennans	4.0	3.3	6.0	5.9	8.9***
Plantago	0.5	0.2	4.4**	1.1	0.9
Eryngium ovinum	0.2	0.1	1.1	1.0	6.1***
Calocephalus citreus	1.2	2.0	2.4	1.8	3.9
Linum marginale	3.5	0.7	3.7	5.8	8.9***
Wahlenbergia	1.2	0.8	4.1	6.9***	8.9***
Geranium retrorsum	4.3	4.0	2.6	4.1	8.9***
Asperula conferta	1.0	3.8	8.6***	8.4***	9.0***
Vittadinia muelleri	0.5	0.1	8.5***	7.4***	8.6***
Brachyscome	3.6	2.9	2.9	7.6*	8.9***

Broadacre weed control and soil fertility run down for grassland regeneration

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Abstract Preparation of sites for native grassland regeneration involves the management of weeds and soil fertility rundown. This is because native grasses are not suited to high soil fertility as other introduced species outcompete them for soil, water and light resources. Soil fertility rundown strategies such as soil scalping have been previously used for grassland restoration but are often cost prohibitive on a large scale.

Management of soil fertility and weeds on a broadacre scale is of fundamental importance to maintaining and restoring biodiversity in the Western Grassland Reserve. The effect of cropping and harvesting from sites is known to reduce fertility in agricultural systems. These methods of management have been used for primary production purposes in the past.

This project examines the use of soil fertility and weed management systems that are applicable to broadacre areas of grasslands for areas that were formerly cropped. The management plans have been developed in consultation with the Arthur Rylah Institute and utilise knowledge gained from expert workshops.

In its first year the site was sown to barley, with and without fertiliser, whilst in crop weed control was undertaken. In the second year a broadleaf crop will be sown to enable grass selective weed control of *Nassella* weed species during the crop growth stage.

Approaches to preventing dispersal of *Nassella neesiana*: investigation of a non-destructive technique for detecting a needle in a hay stack

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Trade in fodder for livestock production in Australia has become of increased importance during the late 20th and early 21st centuries. Part of this trade includes 'relief' fodder. Relief fodder is required by graziers who have been affected by natural disasters of drought, bushfire and flood, to enable recovery of livestock production. The types of bales supplied include pasture hay, which is the cut, dried and baled remains of whole plants from improved pastures (Suttie 2000). These types of pastures may contain a variety of fodder plants and a range of weeds, including those declared noxious. Preliminary work in Australia and elsewhere has determined that bales of pasture hay typically contain the mature seeds of many, if not all, of the species that are present in a pasture. However, the techniques used to make this determination are cumbersome, time consuming and destructive of entire bales that may otherwise have been used to feed livestock (Thomas *et al.* 1984, Wells *et al.* 1986, Conn *et al.* 2010). Therefore, there is an urgent need to develop a reliable method that is rapid and non-destructive of bales. The desired outcome should enhance biosecurity in agriculture, whereby bales that contain seeds of noxious weed species are not dispersed from infested pastures to non-infested regions.

Core samples are already routinely taken from hay bales for feed quality analysis (Collins *et al.* 2000, AFIA 2007, Samuel Roberts Noble Foundation 2007). This technique was investigated to determine whether it could also be applied to detect weed seeds in round pasture hay bales. To elicit a dose-response result for seed load, heat-killed seeds of a noxious grass species (*Nassella neesiana* Chilean needle grass) were added to bales of rye/cocksfoot hay in varying weights (50 g, 100 g, 150 g, 250 g and 1000 g). The seeds were added in three different distribution patterns (even, inner and outer) to mimic expected in-pasture distributions of this weed. My study found that the number of seeds found was positively correlated with the weight of seed added, but showed variation between distribution patterns. Even dispersal gave an almost linear dose-response relationship, but this result was variable between weights for the two remaining distribution patterns. The results obtained indicate that the use of core samples to detect weed seeds in round hay bales has merit and is worthy of further investigation.

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A potential new project on the biological control of wandering trad, *Tradescantia fluminensis* Vell. (Commelinaceae) in Australia

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Abstract *Tradescantia fluminensis* is a herbaceous creeper that comes from South America and is thought to have been introduced into Australia as an ornamental plant. It is now recognised as a very serious environmental weed invading disturbed areas, natural forest, riparian zones, urban areas and wetlands of south eastern Australia and subtropical Queensland. It can also cause allergic reactions to humans and dogs with unknown impacts on indigenous fauna. It prevents forest regeneration and such threats to biodiversity has seen *T. fluminensis* targeted for a biological control program in New Zealand. Overseas explorations in Brazil by New Zealand Landcare Research have identified a guild of potential biological agents with three Chrysomelid beetles (*Neolema ogloblini, N. abbreviata* and *Lema basicostata*) and the yellow leaf spot fungus (*Kordyana* sp.) now approved for release. *Neolema ogloblini* and *L. basicostata* have been released in New Zealand and establishment results are looking promising. Australia is now preparing an application to get *T. fluminensis* declared a Target for Biological Control with the aim of benefiting from the pioneering work undertaken by New Zealand. Availability of agents already screened for hyperparasites/diseases and access to New Zealand host specificity data could enable a relatively fast and cost effective biological control project on *T. fluminensis* for Australia. Should funding become available for biological control of T. *fluminensis*, such a project could result in substantial savings in time and future control costs for Water Authorities, State Parks, Local Government Councils, Landcare/Friends of groups and urban communities in Australia.

Full paper to be presented at the 19th Australasian Weeds Conference, to be held in Hobart, Australia 1–4 September 2014.

Understanding the biology and eco-physiology of poverty weed (*Iva axillaris* Pursh) – a guide towards eradication and control programs in Victoria

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Abstract Poverty weed is a state prohibited weed (SPW) in Victoria. A weed is declared as such, either because it does not occur in Victoria, or there is an expectation it can be eradicated from the state. Understanding eco-physiology and biology of poverty weed is paramount in any eradication or control programs. It may be possible to eradicate poverty weed in Victoria through understanding its biology and eco-physiology, using the integrated weed control approach and also through education and legislation enforcement. This paper aims to review literature on general weed control legislation, biology and eco-physiology of poverty weed and integrated weed management methods thereby providing eradication and control guidelines and recommendations that may be used in current and future management programs.

Keywords Biology, eco-physiology, eradication, poverty weed, state prohibited weed.

INTRODUCTION

Poverty weed is a herbaceous perennial weed that belongs to the Asteraceae family and is native to North America. It is a highly invasive weed that aggressively competes with native species (Richardson *et al*. 2007). Eradication is the management goal for all State Prohibited Weeds (SPWs) in Victoria. Dodd (1990) reported that although eradication is often prescribed as a management goal, in general it is seldom achieved. Hester *et al*. (2004) suggested that eradication is technically feasible for both large and small infestations but only economically feasible for small infestations. Therefore, poverty weed eradication may be both technically and economically feasible in Victoria, as the known and recorded infestation size is less than 50 hectares. This can be achieved by using weed control legislation (Hester *et al*. 2004), knowledge of the biology and eco-physiology of the weeds, and using an integrated weed management approach.

This paper reviews poverty weed literature in relation to these tools, thereby providing eradication and control guidelines, and recommendations that may be used in current and future management programs. Emphasis is mostly directed on the understanding of the biology and eco-physiology of the weeds, as this is the fundamental principle for effective invasive weed management protocols.

BACKGROUND

Poverty weed is a strong competitor and reduces crop yields (Richardson *et al*. 2007). Poverty weed is also allelopathic, and is often the only species present in dense infestations (California Department of Food and Agriculture 2013). Pasture areas in Western Canada that are densely populated with poverty weed have been reported to have become of little or no value for grazing (Best 1975). Poverty weed is a selenium accumulator and may be toxic to livestock when ingested (California Department of Food and Agriculture 2013). Fortunately, it is not palatable (Tasmania Weed Alert Network 2013), hence, the poisoning risk to livestock is minimal. Poverty weed pollen is highly allergenic and plants may cause contact dermatitis to sensitive individuals (Bassett *et al*. 1962).

In Victoria, recorded poverty weed infestations are restricted to a few small patches in Quambatook and Dingwall, with a total infested area of less than 50 ha. These Victorian infestations rarely produce viable seed (Pritchard 1987) and date back to 1967. The only other infestations ever recorded in Australia were in South Australia (SA) in 1933, at Riverton and Sevenhill (SA Government 2004). These were successfully eradicated; there have been no further reports of poverty weed again on those sites.

ERADICATION AND WEED MANAGEMENT TOOLS

Legislation

In some states and territories, local government and catchment management authorities play a major role in the administration of state and territory legislation. Although it is the responsibility of each jurisdiction (Australian Government, state and territory governments) to administer their respective legislation, it is the responsibility of every land manager or individual to be aware of pest management legislation, and to act in accordance with this legislation.

States and Territories Responsibility for the use and management of land rests primarily with the states and territories under the Australian Constitution. Each state and territory has legislation covering the control of some noxious weeds and the movement of weeds and weed seeds, including crop seeds and stock feed. The legislation empowers governments to compel landholders and occupiers to control certain weeds and to prevent their movement and spread.

Victorian legislation Under the *Catchment and Land Protection Act 1994* (CaLP Act) noxious plants are classified under four categories: State Prohibited Weeds, Regionally Prohibited Weeds, Regionally Controlled Weeds and Restricted Weeds. Poverty weed is classed as a State Prohibited Weed. This is the highest category of noxious weeds under this act. The Victorian Government, through the Department of Environment and Primary Industries, has the sole responsibility for treatment and management of SPWs, but may direct land owners to prevent their growth and spread. Details of the other categories can be found in the CaLP Act (*CaLP Act 1994*, Reprint No 4 2006).

Understanding the biology of poverty weed

Knowledge and in-depth understanding of the ecophysiology and biology of poverty weed is of paramount importance in eradication and control programs. However, there is currently limited literature worldwide on poverty weed; published scientific research is almost non-existent. Richardson *et al*. (2007) reported that very little is known about the biology of poverty weed. The very few published materials on eradication and control options are outdated. The reason for the lack of research and scientific interest could not be established.

Morphology and identification Poverty weed is an erect, multi-stemmed, perennial herb, 20–40 cm tall (Richardson *et al.* 2007). Stems are bushy and mostly branched from a woody crown. The leaves are narrowly elliptic to obovate, with rounded tips, 1–4 cm long and leaf margins are smooth. Leaves are grey-green in colour, stalkless and may be hairy. Lower leaves are arranged opposite one another on the stem, while upper leaves are arranged alternately. The leaves emit a strong, unpleasant odour when crushed (Richardson *et al*. 2007).

The flowers are wind-pollinated (California Department of Food and Agriculture 2013) and the flower heads are greenish, nodding on short stalks, solitary in upper leaf axils, consisting of 5–20 staminate disc flowers surrounded by 1–5 fertile pistillate flowers with tiny tubular corollas (Richardson *et al*. 2007). Kramer (2007) described the flowers as inconspicuous.

The seed is egg-shaped, flattened, brown to grey-coloured, and 2–3 mm long, with six or seven seeds produced by each flower head (California Department of Food and Agriculture 2013) and lacks a pappus.

The roots are woody and highly branched, slender and deep (to 2.5 m) with numerous shoots buds. This deep and extensive root system allows poverty weed to persist over winter or under drought conditions (Richardson *et al*. 2007).

Best (1975) reported that poverty weed is less likely mistaken for other plants apart from perennial ragweed (*Ambrosia coronopifolia*). He further noted that although perennial ragweed also has creeping rootstock and is a similar height to poverty weed, it has lobed leaves and the flower head contains only one kind of flower (Frankton and Mulligan 1970), distinguishing it from poverty weed.

Reproduction and dispersal Poverty weed reproduces vegetatively by rhizomes and by seeds. Long-distance dispersal is through transport of rhizome fragments on contaminated machinery and vehicles (Richardson *et al*. 2007). Deep roots can survive repeated cultivation for several years and cultivation has been reported to disperse root fragments (Best 1975, Richardson *et al*. 2007). Best (1975) reported that deep roots could remain dormant for long periods under intense competition and produced new shoots under drought conditions. In post senescence roots survive, but foliage dies back in cold winter climates. Richardson *et al*. (2007) reported that the plant died back to ground level in late summer.

Seeds are not wind-dispersed, however, they can move long distances in water and with agricultural machinery, but primarily disperse near the parent plant. Seed can survive ~8 months submergence in water. Newly matured seeds are normally dormant and seldom develop into seedlings (Best 1975). There is however, an information gap on seed viability (California Department of Food and Agriculture 2013). Pritchard (1987) reported that Victorian infestations rarely produced viable seed. Poverty weed is an obligate out-crosser, requiring pollen from other plants for successful fertilization.

Eco-physiology Poverty weed is generally found in poorly drained alkaline regions, on clay and clay loam soils and frequently in cultivated fields (Bassett *et al*. 1962, Best 1975) but may also be found on other soil types and in high, well-drained locations (Godel 1934, Harding 1939). It may also persist along roadsides, cultivated fields and salt marsh areas (Best 1975, California Department of Food and Agriculture 2013). In Victoria, Poverty weed infestations are on sandy loam soils.

Integrated weed management

An integrated weed management approach is the universal general weed management recommendation (Slater 1998). This comprises of chemical, biological, mechanical and cultural methods. Chemical treatment is the most effective control method for poverty weed (Pritchard 1987). Although poverty weed eradication is difficult (Parsons 1962), it is not impossible (Woods 2013).

Chemical control Research in Australia showed that high volume spot applications of 0.3% v/v clopyralid, 0.2% v/v picloram + 0.8% v/v 2,4-D were effective for short-term control (Pritchard 1987). Extended control for 1 or 2 years and a very high level of control for 3 years was obtained with 0.1% v/v picloram + 0.4% v/v 2,4-D, 0.8% v/v dicamba, and 0.72% v/v glyphosate applied spray-to-wet.

Recently, poverty weed treatment with Lontrel (300 g/L clopyralid as the triisopropanolamine salt) at a Dingwall site in Victoria was found to highly suppress the weed (Hansford 2010). The application rate was 500 mL of product per 100 L spray mix – hand gun and 4 L product/ha (boom). This now forms the basis of the current treatment recommendation for all sites under the Victorian poverty weed program (Hansford 2010).

Research from Canada has shown 2,4-D to be highly effective at high rates. However, poverty weed was found to be resistant to 2,4-D at rates that are recommended for use in cultivated crops (Harris and Cords 1964, Best 1975). Picloram at 0.84 kg/ha on non-crop land and permanent pastures will control poverty weed, although some grass damage may result (Frankton and Mulligan 1970).

Other non-chemical methods All other non-chemical eradication methods reported to have been tried independently were not successful. All tried tillage methods failed to eradicate the weed (Best 1975) and was found to actually help to disperse the weed through machinery and cultivation equipment. Poverty weed has reported to be effectively kept in check on the western prairies by an alternating wheat (*Triticum aestivum* L.) and summer-fallow system (Best 1975). Perennial hay crops such as smooth brome (*Bromus inermis*), crested wheatgrass (*Agropyron cristatum*), alfalfa (*Medicago sativa*) and sweet clover (*Melilotus officinalis*) have been reported to suppress poverty weed to some extent (Chepil 1936). Animals were found to learn to avoid it (Best 1975) so their use is not a recommended control method. Several biological control methods have been reported for poverty weed but there are no records for any biological control agents that have successfully completely eradicated it. Hand pulling and controlled burning is not effective since poverty weed is a deep-rooted perennial, and a natural component of many grassland communities that experience periodic fires. Regrowth is likely to occur on mowing with no long-term damage to the plant.

CONCLUSION

It can be concluded that eradication of poverty weed in Victoria may still be feasible since the infestation is still small, localised and that the plant is highly distinguishable. This can be effectively attempted by using weed control legislation, knowledge of the biology and eco-physiology of the weeds, and utilising an integrated weed management approach as the prescribed tools in the eradication programs. With sufficient resources, staff commitment and key stakeholder engagement, eradication is potentially an achievable goal. Even if full eradication is unsuccessful, these tools, used concurrently will still achieve ongoing suppression.

RECOMMENDATIONS

- Use of integrated weed management principles.
- Rotating herbicides and use of surfactants.
- Correct timing of herbicide application.
- Follow-up treatments.
- Machinery and farm hygiene.
- Landholder education and engagement.
- Strict legislation enforcement.
- Intensive site monitoring, robust record keeping and detailed mapping.
- High level of staff commitment and thorough contractor supervision.

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Karoo thorn, *Vachellia (Acacia) karroo*: a State prohibited weed close to eradication

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Abstract Karoo thorn, *Vachellia (Acacia) karroo* is a thorny tree from Africa. It was declared a State prohibited weed under the *Catchment and Land Protection Act 1994* in May 2003. State prohibited weeds are to be targeted with eradication from Victoria by the Department of Environment and Primary Industries (DEPI).

In Victoria, Karoo thorn has been detected only as a very rarely planted tree in botanic gardens, zoos, parks, and a few other situations. The species has not been recorded as naturalised in Victoria, nor has it been recorded as being traded in Victoria. With nearly all known sites deemed eradicated in recent years by DEPI, there are now only three known infestation sites left in Victoria, and each of these sites is in a 'monitoring-only' status. Further, no new sites have been detected in Victoria since 2004, despite this species having been targeted for detection by Weed Spotters for the last 10 years. The three remaining 'monitoring-only' sites are likely to be progressively deemed eradicated as their 'monitoring-only' period ends over the next few years. This species shows a very promising trend towards eradication from Victoria, a target that is considered easier to achieve in this case than with many others due to the favourable characteristics of the species and the nature of its incursion.

Keywords Karoo thorn, *Vachellia karroo*, *Acacia karroo*, State prohibited weed, eradication.

INTRODUCTION

Description

Karoo thorn, *Vachellia (Acacia) karroo* is a thorny tree native to southern Africa. It may grow to 12 m or more in height. It has paired thorns, usually up to 100 mm long, or occasionally as long as 250 mm. The leaves are light green and fern-like, up to 120 mm long and about 50 mm wide, and composed of 8–20 pairs of small oblong leaflets. Fluffy yellow ball-shaped flowers, 10–15 mm in diameter, grow in clusters of between four and six and are sweetly scented. The seed pods, which grow up to 160 mm long and 10 mm wide, are sickle-shaped, woody and slightly constricted between the seeds. The tree is usually evergreen but may lose its leaves in droughts or other extreme conditions (CRC for Australian Weed Management 2003).

Reproduction, dispersal and seed longevity

Karoo thorn reproduces by seed, with large trees producing up to 19,000 seeds per year (CRC for Australian Weed Management 2003). When the pods burst, the hard-coated seeds tend to fall straight to the ground beneath the tree. The seeds have a longevity in the soil of up to 7 years (du Toit 1972). Seeds are mainly dispersed by grazing mammals ingesting the seeds and dispersing them in their droppings, with wind and water considered less important means of dispersal (Story 1952, O'Connor 1995).

Distribution and status as a weed

Africa and Europe In many parts of its native range in southern Africa, Karoo thorn is considered a weed due to it being a vigorous competitor and invader of rangelands and grasslands, with the ability to form dense impenetrable thorny thickets (CRC for Australian Weed Management 2003). Karoo thorn has been introduced outside its native range to other parts of the world and has naturalised in Spain and Portugal (University of Queensland 2011).

Australia Karoo thorn seeds are a prohibited entry to Australia due to the weed risk of the species (Department of Agriculture Fisheries and Forestry 2013). Karoo thorn is also one of the 28 species listed on the National Environmental Alert List (CRC for Australian Weed Management 2003).

Despite being a prohibited import to Australia in recent times, seed of Karoo thorn previously found its way into Australia as trees have been found growing in botanic gardens, zoos and as specimens in private gardens. These isolated cases appear to have only been grown by enthusiasts and thankfully not promoted by the nursery and garden industry in Australia.

Western Australia Status: Karoo thorn is a declared noxious weed in the categories of 'P1' (prohibit movement), and 'P2' (eradicate all infestations).

Pre-emptive action has prevented further spread from historically planted trees through their removal from zoos and botanic gardens. All African 'Acacia' species, including Karoo thorn were removed from the Perth Zoo in 2001; and Karoo thorn trees found growing at Kings Park, Midlands and at Caroo have also been removed (Sandy Lloyd, pers. com 2007).

New South Wales Status: Karoo thorn is a declared noxious weed in the category of 'State prohibited' (Class 1, notifiable). Pre-emptive action was taken to remove of a stand of Karoo thorn trees that had been growing by a beach at Stockton near Newcastle (Syd Lisle NSW DPI, pers. comm. 2004). Karoo thorn had also spread from its original plantings at the Dubbo Western Plains Zoo and required an eradication campaign at the zoo (CRC for Australian Weed Management 2003).

Queensland Status: Karoo thorn is a declared noxious weed in the category 'Class 1', (eradicate). In 2008, about 20 'naturalised' specimens of Karoo thorn were detected on the Darling Downs, Queensland. These where confined to one small site and were derived from a seed bank from an old tree that had been cut down and burned by the landowner. The origin of the original tree was unknown. All of the regenerating trees were removed and the site is continuing to be monitored (Csurhes *et al.* 2010).

South Australia Status: Not declared. Although not declared in South Australia, pre-emptive action saw the removal of the two Karoo thorn trees that were growing at the University of Adelaide's Waite Arboretum in 2002 (CRC for Australian Weed Management 2003).

Victoria Status: Karoo thorn is a declared noxious weed in the category 'State prohibited' (eradicate). It was declared a State prohibited weed in May 2003 under the *Catchment and Land Protection Act 1994*. State prohibited weeds are to be targeted with eradication from Victoria by DEPI. Eight sites of Karoo thorn were detected from the late 1990s to 2004, with all trees having been removed by DEPI from each of these sites. In addition, historical herbarium records led to the discovery of two further sites where Karoo thorn had been detected many years earlier but, when surveyed by DEPI in 2004, it was found to be no longer present. These sites are considered 'surveillance sites' rather than actual infestation sites. Karoo thorn is not considered naturalised in Victoria, and the only seedlings that have been found in Victoria were growing underneath one tree prior to its removal at the Werribee Open Range Zoo in 2004 (Hansford 2004).

With no new Karoo thorn sites detected in Victoria since 2004, this species shows a very promising trend towards eradication from Victoria. The following sections of this paper provide the methods, data, trends and current extent of Karoo thorn in Victoria.

MATERIALS AND METHODS

Detection

National Herbarium of Victoria DEPI staff worked with National Herbarium of Victoria staff in 2003/04 to search their collections for herbarium records of Karoo thorn in Victoria. Three site records (Site 6 in Table 1, and Sites 1 and 2 in Table 2), were detected in this way, and had previously been unknown to DEPI.

Communications with botanical professionals As Karoo thorn has been very rarely cultivated in Victoria, it was thought by engaging with botanical professionals (such as Herbarium staff, and horticultural and heritage tree experts), that they may know of additional cultivated specimens in Victoria. Four site records, (Sites 3, 5, 7 and 8 in Table 1) were detected in this way in 2003/04, and had previously been unknown to DEPI.

Plant database searches Plant databases were searched, including Australia's Virtual Herbarium (http://avh.chah.org.au/), and DEPI's internal Flora Information System. No Victorian records of Karoo thorn were found on these databases.

Weed Spotters Passive detection efforts by Weed Spotters (http://www.depi.vic.gov.au/agriculture-and-food/pests-diseases-and-weeds/weeds/weed-spotters), who are volunteers trained to look for State prohibited weeds (including Karoo thorn), have, so far, not detected any Karoo thorn.

Public reports DEPI encourages members of the public to report State prohibited weeds. Despite several public reports of Karoo thorn having been made over the years, none have been officially identified as Karoo thorn.

Surveillance of Victoria's regional botanic gardens During the 2000s, DEPI staff surveyed Victoria's regional botanic gardens to look for the presence of State prohibited weeds (including Karoo thorn). No new Karoo thorn sites were detected in this way.

Treatment

The standard treatment was the physical removal of each entire tree, including its stump and roots, using arborist contractors who chipped the material into a receiving truck. Then, the area of topsoil that had been underneath the canopy of each tree was scraped to a level of approximately 5–10 cm deep to remove a 'possible seed bank'. All removed material was then trucked to a landfill site and disposed of by deep burial. Contractors also paid attention to hygiene protocols throughout the removal and disposal process. As the sites were all within public gardens and zoos, attention was also paid to site rehabilitation, so that each site was left in a tidy condition after treatment, with topsoil, grass and vegetation often replaced at the end of treatment. In a small number of cases, treatment did not follow the standard procedure, and no soil was scraped. For example, a single large tree at the Werribee Open Range Zoo was considered a valuable part of the cheetah exhibit by the zoo. In this case the tree was killed by stem injection with herbicide and the dead tree was left standing. This was an acceptable compromise, and important for the zoo, as the presence of the dead tree was still considered structurally important to the landscape of the exhibit.

Monitoring

After tree removal, each site was monitored annually. When a period of seven 'clear' years of monitoring after tree removal was reached, it qualified for eradication assessment.

Eradication assessment

Even though the probable area of seed bank had been removed in most cases, there could be no guarantee that every single seed or every part of a possible seed bank had been removed by this process. Also because, in some cases, the seed bank had not been removed, it was decided to continue to monitor all sites up to a point at which there could be confidence that any seed left in the soil would have expired. The monitoring period prior to eradication assessment was therefore set at seven years, as this is considered the maximum life of seed in the soil for Karoo thorn (Du Toit 1972).

After seven years, each site was assessed according to a set of criteria to determine whether there was any missing information. The criteria included whether the area surrounding each site had been surveyed (ie. delimited), and whether trace-forward and trace-back investigations had been carried out. Finally, when all of the eradication criteria had been met for a particular site, the site was finally deemed 'eradicated'. This status was then updated on the database.

Data management

Data was stored in electronic format on DEPI's Integrated Pest Management Information System (IPMS). The database was used to collect the data for infestations, assessments, and treatments of declared weeds in Victoria. In 2012, all IPMS data on State prohibited weeds was transferred to a new database: DEPI's Invasive Species Information System (ISIS). Data on each Karoo thorn site is also stored in hard-copy format as a file for each infested property.

Site definitions

The basic unit of a Karoo thorn site is called an 'infestation' or 'site'. Each infestation of Karoo thorn consists of either a single tree or several trees of Karoo thorn that were found growing at each property. The IPMS database uses the site unit of infestation to refer to the presence of one weed species on one property. Therefore the number of infestations always equals the number of infested properties for each weed species. The infested area of each infestation has been defined as the estimated area of a possible seed bank, and is generally the area covered by the canopy of Karoo thorn trees at each site, plus any additional area considered to possibly contain seed of the target weed. In most cases the infested area can only be estimated, as the extent of a seed bank cannot be seen by an observer and so is often exaggerated to account for the risk of approximation. As each infestation has been deemed eradicated, the infested area of that site is adjusted to zero. Thus, as the eradication of infestations proceeds, both the total number of sites (number of infestations) and the total infested area decreases. The eradication (of known sites) will be complete when the total figures for both site numbers and infested area are adjusted to zero.

RESULTS

Victoria's Karoo thorn infestations

Tables 1 and 2 provide details of Victoria's Karoo thorn infestations, their detection, treatment and current status.

The total 'infested area' of Karoo thorn in Victoria is currently 0.5029 ha, which is the area of presumed seed bank that may still exist at the three remaining monitoring sites. As these monitoring sites are progressively deemed eradicated over the next few

Table 1. Victoria's Karoo thorn infestations (sites).

Site	Location	Site description	Detection of site	Trace-back	Trace-forward	Delimitation	Treatment of site	Status of site in 2013/14
1	Parkville	At Melbourne Zoo: 12 large trees in the lion enclosure.	DEPI officers became aware of site in 1990s, via liaison with the zoo. Site first recorded on IPMS database in 2003.	Trees planted in 1968. Seed donated by a visiting Joy Adamson, author of 'Born Free'*	Seed from these trees was used to grow the trees at the Werribee Open Range Zoo**	Melbourne Zoo grounds checked by DEPI in 2003. Nothing found.	In 2003, all trees removed, topsoil scraped from under trees. All waste to landfill.	Eradicated
2	East Melbourne	One large tree growing in Yarra Park (managed by City of Melbourne)	DEPI officers became aware of site in 1990s (uncertain how detected). Site first recorded on IPMS database in 2003.	A very old tree, date of planting or origin of the seed is uncertain.	The tree was in a public park, but it is unknown if anyone had ever tried to propagate from it.	Yarra Park was foot searched by DEPI in 2003. Nothing found.	In 2003, the tree was removed, topsoil scraped from under tree. All waste to landfill.	Eradicated
3	Bendigo	One large tree growing in the White Hills Botanic Gardens.	DEPI officers became aware of site in 2003 after liaison with botanical professionals from Heritage Victoria, as the very old tree was Heritage-listed. Site first recorded on IPMS database in 2003.	A very old tree, date of planting or origin of the seed is uncertain.	The tree was in a public park, but it is unknown if anyone had ever tried to propagate from it.	White Hills Botanic Gardens and surrounding area was foot searched by DEPI in 2007. Nothing found.	In 2010, the tree died of a fungal disease. In 2011, the tree was removed, topsoil scraped from under tree. All waste to landfill.	Monitoring
4	Werribee	Werribee Open Range Zoo: 21 large trees including five trees in the meerkat and cheetah enclosures.	DEPI officers became aware of site in 2003 after liaison with Melbourne Zoo in 2003. Site first recorded on IPMS database in 2003.	Seed originally obtained from the Melbourne Zoo trees.	Trees not further propagated by Werribee Zoo	Werribee Zoo grounds checked by DEPI in 2004. Nothing found.	In 2004, 16 trees and topsoil underneath were removed. In 2007, five remaining trees were removed***. All waste to landfill.	Monitoring
5	Melbourne	One large tree growing in the Royal Botanic Gardens Melbourne.	DEPI officers became aware of site in 2003 after liaison with botanical professionals (Royal Botanic Gardens staff). Site first recorded on IPMS database in 2004.	A very old tree, date of planting or origin of the seed is uncertain.	According to gardens staff, the tree was observed to never produce any seed, although it flowered each year.	N/A. Tree never observed to produce seed.	In 2004, tree removed. All waste to landfill.	Eradicated

Table 1. Continued on next page.

Table 1. Continued from previous page.

Site	Location	Site description	Detection of site	Trace-back	Trace-forward	Delimitation	Treatment of site	Status of site in 2013/14
6	Hawthorn	One large tree growing at St James Park (managed by City of Boroondara)	DEPI officers became aware of site in 2003 after searching the internal database of the Royal Herbarium of Victoria. Site first recorded on IPMS database in 2004.	A very old tree, date of planting or origin of the seed is uncertain.	The tree was in a public park, but it is unknown if anyone had ever tried to propagate from it.	St James Park checked by DEPI in 2004. Nothing found.	In 2004, the tree was removed, topsoil scraped from under tree. All waste to landfill.	Eradicated
7	Burnley	One tree growing at the Burnley campus of University of Melbourne	DEPI officers became aware of site in 2003 through liaison with botanical professionals (Burnley campus staff). Site first recorded on IPMS database in 2004.	A very old tree, date of planting or origin of the seed is uncertain.	The tree was in a public garden, but it is unknown if anyone had ever tried to propagate from it.	Burnley campus checked by DEPI in 2004. Nothing found.	In 2004, the tree was removed. All waste to landfill.	Eradicated
8	Williamstown	One large tree growing in a church yard.	DEPI officers became aware of site in 2003 after liaison with botanical professionals from Heritage Victoria, as the very old tree was Heritage-listed. Site first recorded on IPMS database in 2004.	A very old tree, date of planting or origin of the seed is uncertain.	Unknown if anyone had ever tried to propagate from it.	Church and surrounds checked by DEPI in 2011. Nothing found.	In 2010, DEPI applied for a Heritage permit to remove the tree. Permit was granted. In 2011, the tree was removed, topsoil scraped from under tree. All waste to landfill.	Monitoring

Notes
*Colin Knight, Melbourne Zoo, pers. comm 2003.
**Richard Rowe, Werribee Open Range Zoo, pers. comm 2004.
***One tree at the cheetah enclosure at the Werribee Open Range Zoo was not removed (at the request of the zoo). Instead, it was killed by herbicide stem-injection and left standing as a dead tree to help maintain the African landscape values of the cheetah exhibit.

Table 2. Surveillance sites (Karoo thorn never seen or confirmed by DEPI, but historical herbarium records exist).

Site	Location	Site description	Detection of site	Trace-back	Trace-forward	Delimitation	Treatment of site	Status of site in 2013/14
1	Gooramadda	Described as a single tree in text on a herbarium specimen dated 1937. Tree never sited by DEPI. A surveillance site only.	DEPI officers became aware of site in 2004 after searching the internal database of the Royal Herbarium of Victoria. Site recorded on IPMS as a surveillance record only.	No information	No information	The ruins of the old town of Gooramadda, near Rutherglen, were surveyed by DEPI in 2004. Surrounding area surveyed by foot and vehicle. Nothing seen.	N/A. Tree never sited by DEPI. The tree probably died many years ago or was removed by persons unknown.	Surveillance
2	Bendigo	Lake Weeroona, Bendigo. Described as a single tree in text on a herbarium specimen dated 1984. Tree never sited by DEPI. A surveillance site only.	DEPI officers became aware of site in 2004 after searching the internal database of the Royal Herbarium of Victoria. Site recorded on IPMS as a surveillance record only.	No information	No information	Entire Lake Weeroona reserve surveyed on foot by DEPI in 2004. Nothing seen.	N/A. Tree never sited by DEPI. The tree probably died many years ago or was removed by persons unknown.	Surveillance

years, the infested area will be progressively adjusted down to zero.

Chronology of detection and eradication progress over time Table 3 and Figure 1 show data from the ISIS/IPMS database on Karoo thorn infestation sites. The Karoo thorn detection and eradication project begun in 2002/03, the year that the first sites were entered into the IPMS database. However, all eight sites had been present in Victoria for many years prior to their detection and first database entries.

DISCUSSION

Figure 1 displays the data from Table 3 to show the change in status of Karoo thorn sites over time. At seven years since tree removal, each infestation site was assessed for eradication and then deemed eradicated, as no regrowth had been observed at any treated sites during this period. Thus, with the removal of the last known Karoo thorn trees having taken place in 2010/11, it is expected that all known sites of this species will be able to be deemed eradicated from Victoria seven years later, i.e. in 2017/18.

How confident can we be that eradication will be achieved?

Are there any more undetected Karoo thorn trees in Victoria? It is possible that there are more undetected Karoo thorn trees in Victoria, but the likelihood is low. This is because, following the exhaustive active detection efforts of 2003 and 2004, which involved searching botanical databases and working with botanical professionals to identify sites, there have been no new trees detected since 2004. The species has also been a target of passive detection efforts by DEPI's trained Weed Spotters for many years, and still no new sites have been detected since 2004. Nevertheless, there will always be the possibility that an undetected tree will one day be discovered.

Seed longevity Du Toit (1972) refers to a soil seed life of up to seven years for Karoo thorn, but more

Table 3. Karoo thorn: chronology of progress on detection and eradication over time.

Year	No. of *Treatment sites	No. of *Monitor-only sites	No. of *Eradicated sites	New sites detected	Total sites
2001/02	0	0	0	0	0
2002/03	2	0	0	2	2
2003/04	5	2	0	5	7
2004/05	3	5	0	1	8
2005/06	3	5	0	0	8
2006/07	3	5	0	0	8
2007/08	3	5	0	0	8
2008/09	2	1	5	0	8
2009/10	2	1	5	0	8
2010/11	0	3	5	0	8
2011/12	0	3	5	0	8
2012/13	0	3	5	0	8
2013/14	0	3	5	0	8

*Eradication status terminology, as published in Panetta (2007). The first status is the 'treatment' phase, the second is 'monitor-only' phase, 'eradicated' is the final status of a site.

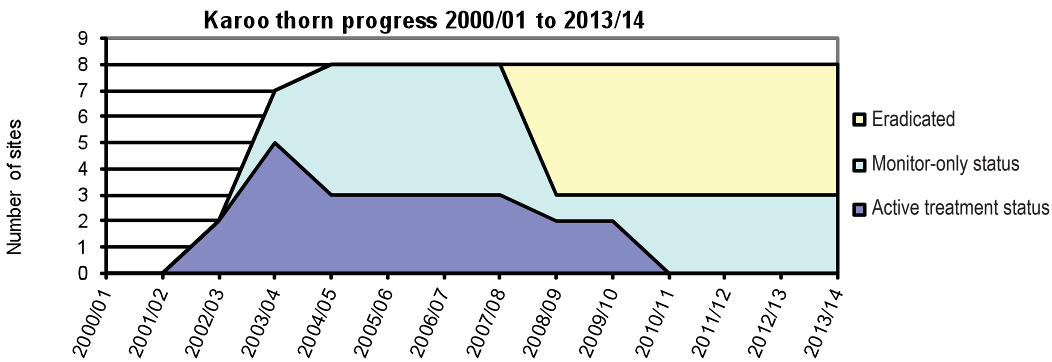

Figure 1. Karoo thorn: Chronology of progress on detection and eradication over time.

recent work (O'Connor *et al.* 2010) suggested that Karoo thorn seed mostly had either germinated or degraded after just one or two years in the soil. However, to provide the best confidence for eradication in this project, the upper limit of seven years was chosen. Other factors also contribute to confidence that none of the treated sites will ever re-grow:

1. Most of the sites had the presumed area of seed bank physically removed from under each tree. This means the seven years of monitoring was only done for any seed that was possibly left behind, and for those trees where seed bank removal was not undertaken.
2. The practice of seed bank removal was probably an unnecessary step in several cases. Certainly, some of the trees were not observed to have produced any seed at all, and could therefore not have had a seed bank. For example, the tree at the Royal Botanic Gardens Melbourne (Table 1, Site 5) had been closely observed by Gardens' staff for many

years and had never been observed to produce any seed, although it was observed to flower each year. The reason for this is probably because Karoo thorn tends to be an outcrossing species (O'Connor *et al.* 2010), and sometimes isolated trees without access to cross-pollination will not be able to form seed. Six out of the eight Karoo thorn infestations consisted of a single isolated tree only. However, the tree at the White Hills Botanic Gardens Bendigo was an isolated tree, and it was able to produce seed, and the viability of collected seed was confirmed by a germination test. So, it seems that some isolated trees are able to self-pollinate whilst others are not.

Seed dispersal and delimitation In its native range in southern Africa, grazing mammals, particularly cattle, were found to be the main means of seed dispersal (O'Connor *et al*. 2010), whereby seed is ingested and later passed through the gut at some distance from where the seed was originally ingested. Otherwise, Karoo thorn seeds have no particular means of dispersal. For example, the seeds are hard and smooth and would be unlikely to be carried by wind or water for any great distance. So, the default situation is that seed falls straight to the ground from each tree and lies on the soil surface beneath. In the literature, there was no specific mention of bird dispersal of Karoo thorn seeds, only to grazing mammal dispersal. Therefore, because of the nature of Victoria's known Karoo thorn sites (being within zoos and public gardens), grazing mammals would never have had access to any of these sites, and with no apparent means of medium-distance dispersal, there can be confidence that the delimitation surveys so far conducted (being of localised scale) have been of adequate scale, and that no further delimitation surveys are necessary.

Human assisted seed dispersal Could seed have been deliberately collected and dispersed by humans via propagation? Trace-forward investigations showed that seedlings were propagated from the Melbourne Zoo's trees and then planted at the Werribee Open Range Zoo, and that no further zoo propagation had occurred since. Victoria's other Karoo thorn trees were located in parks and gardens, and trace-forward investigations found no evidence that garden staff had propagated from any of these trees. However, these parks and gardens were publicly accessible and it is not known if any person from the public had ever collected seeds from any of these trees. Still, there were no reported instances of anyone having collected seeds from any of these trees.

Future re-introduction into Victoria from overseas or interstate Importation of Karoo thorn seed and plants is prohibited by the Federal Government. This provides confidence that it is unlikely that Karoo thorn will enter Victoria again from overseas, although illegal importation and the importation of mislabelled seed is still a possibility. Karoo thorn trees growing in other states and territories of Australia could also provide a source of propagules to re-infest Victoria in the future, but the risk of this is low because Karoo thorn has only ever been rarely grown anywhere in Australia. Even in the states where Karoo thorn is not declared noxious, such as in South Australia, there have been some attempts at pre-emptive action to remove trees (CRC for Australian Weed Management 2003), and there would unlikely be many known trees left alive in South Australia today that could possibly pose a risk to Victoria. However, what happens to Karoo thorn in other states and territories is beyond Victoria's jurisdiction and beyond the scope of Victoria's current eradication campaign for Karoo thorn. Any future new incursion of Karoo thorn into Victoria would need to be considered as a new and separate incursion and would be managed as a new project.

A good candidate species for eradication

When Karoo thorn was originally declared a State prohibited weed in May 2003, the declaration was done on the basis of a weed risk assessment that showed the species was a potential threat to Victoria, and also that there were only two known sites at that time in Victoria (Sites 1 and 2.: Table 1.). Karoo thorn had been considered a very good candidate for eradication right from the start, and even now, 11 years later, although six more sites were detected in 2004, no more sites have been detected since. Karoo thorn now shows a very promising trend towards eradication from Victoria. This is considered easier to achieve with this species than with many other weeds due to the favourable characteristics of the species and the nature of its incursion.

The favourable characteristics of the species (making it a good candidate for eradication) are:

- An 'out-crossing' species means that many isolated trees would potentially have been unable to form seed.
- Seed has no particular means of dispersal other than being ingested and spread by grazing

mammals. This special requirement has probably limited the spread from the known sites in Victoria.

The favourable characteristics of the nature of the incursion (making it a good candidate for eradication) are:

- The species seems to have only ever been planted rarely in Victoria, principally by zoos, botanic gardens, and occasionally by enthusiasts in public parks or gardens. It does not seem to have been available in the nursery trade. Likewise, the species seems only to have been rarely planted interstate (and in the same situations) as in Victoria, so there are few potential sources of propagules available to re-infest Victoria. The species has also been targeted for eradication in other states, is declared noxious in four states (including Victoria), and is a prohibited import to Australia.
- No trees had been planted in Victoria in a situation in which the prime vector (grazing mammals) had access to any of the trees. Without the prime spread vector being present there could only have been minimal, if any 'natural' spread of the species over time from these sites.
- There was no evidence reported of any unauthorised public propagation from trees in public parks.
- No naturalised populations of Karoo thorn appear to have established in Victoria.
- Many infestations consisted of only one, isolated tree at each site, having been planted as single specimen trees. The isolated planting pattern, combined with the 'out-crossing' characteristics of the tree probably resulted in less seed formation at these sites, and less likelihood of spread from these sites.

CONCLUSION

This project has been successful, and it is very likely that eradication of all of the known sites of Karoo thorn in Victoria will be achieved at the end of their monitoring period in 2017/18. However, eradication of the known sites is all that this project will be able to achieve because we don't know if there are any undetected sites still in Victoria. If, as the years go by, and with the continued passive detection efforts of Weed Spotters, there are still no undetected sites found, confidence will grow that eradication has been achieved. However, it will not be possible to prove that there are no unknown sites out there somewhere. If any unknown sites are detected in the future, these will simply be added to the project and its time frame for completion will be extended to account for the subsequent monitoring period prior to these sites being deemed eradicated. If any new incursions of Karoo thorn (seed or plants) are detected as having been brought into Victoria in the future, this would constitute a new incursion requiring a separate project to manage it, and would not detract from the current project's success, which is on-track to eradicate the known sites of Karoo thorn in just a few years' time.

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Effects of pine-oil and sugar on germination of cane needle grass (*Nassella hyalina*) in a pot trial

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Summary Cane needle grass (*Nassella hyalina* Nees) is perennial exotic unpalatable weedy grass from South America that threatens critically endangered grasslands within the Western Grassland Reserve near Werribee in Victoria. The evolution of weed control practices now places an extremely high emphasis on eradication of new weed incursions before their populations are beyond expiration. A key component of weed eradication is destroying or controlling the weed seed bank. Essential oils have been shown to exhibit herbicidal activity and have been previously used for weed seed bank control. Carbon (sugar) has been shown to increase microbial activity and has also been linked to reducing seed bank germination. This trial examined applications of an essential oil (pine oil) at a range of rates (0, 1%, 2.5%, 5%, 10% and 20%) with and without carbon (sugar at 0.2 kg C/ha) and compared this to a herbicide treatment applied as a pre-emergent herbicide (0.745, 1.49, 2.24 kg a.i./ha flupropanate) on germination of cane needle grass seeds. Results show a strong dose response for decreased seed germinations with increased pine oil concentration, with no seeds germinating at 20% pine oil concentration. No response was observed for carbon addition. Flupropanate granules applied as a pre-emergent herbicide did produce a dose response effect in cane needle grass seed germination, but it was not sufficiently effective to be considered a useful treatment at the rates applied. This work suggests that pine oil at 20% v/v with water may be a practical option for integrated management of spot incursions of cane needle grass.

Stinger herbicide – new option for hard to kill weeds in pasture!

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Abstract Stinger™ Herbicide at 20 g/100 L of water for blackberry and 30 g/100 L of water for gorse, applied by high volume handgun equipment, gave good regrowth suppression two seasons after the initial application when compared to the equivalent rate of metsulfuron-methyl alone.

Stinger also gave residual control of secondary broadleaf weeds, such as broom and thistles, two seasons after the initial application with no affect on grass pastures.

Keywords Aminopyralid, metsulfuron-methyl, blackberry, gorse, Stinger.

INTRODUCTION

Control of hard-to-kill woody weeds, like blackberry (*Rubus fruticosus* L. agg.) and gorse (*Ulex europaeus* L.), have been managed by many different techniques in Australia over the past 50 years. Herbicides play an important role in the management of these weeds and Dow AgroSciences has been at the forefront in researching new herbicides to manage these weeds.

Grazon™ Extra Herbicide (8 g/L aminopyralid + 100 g/L picloram + 300 g/L triclopyr) @ 350–500 mL/100 L water is the commercial standard for the control of gorse and blackberry by the high volume application technique, providing quick brown out and reliable long-term control.

In situations where there are dense blackberry infestations, a less expensive initial knockdown treatment is required before follow-up with Grazon Extra. This is where Stinger is proposed for use.

This paper reports on the final results obtained two seasons after a number of trials were reported by Wells *et al.* (2013), where the initial brown out results and first season results were published for aminopyralid + metsulfuron-methyl, now registered as Stinger™ Herbicide (375 g/kg aminopyralid + 300 g/kg metsulfuron-methyl), compared to metsulfuron-methyl alone for the control of gorse and blackberry, which is commonly used at present.

MATERIALS AND METHODS

Details of the trial sites, treatments and application details were presented in the initial paper by Wells *et al.* (2013). Follow-up assessments have been made at each gorse and blackberry site two seasons after application to determine the overall level of control or regrowth suppression of the different treatments. Results presented are for all weeds and trial sites. Assessment times are shown in days (DAA) or months (MAA) after application. Treatment differences were determined using Analysis of Variance (ANOVA) in Agricultural Research Manager (ARM 8) and least significant difference tests at the 5% probability level (LSD). The coefficient of variation (CV) is also listed for each set of data.

RESULTS

Gorse The second season results from the gorse trials in Victoria are shown in Table 1.

Blackberry The second season results from the blackberry trials have been split into data from New South Wales (Table 2) and Victoria (Table 3).

DISCUSSION

Gorse In two out of the three trials, Stinger was numerically superior to metsulfuron for the control of gorse; however the results were not significant. In trial 123002GW, rainfall occurred soon after the application of the treatments, which may have affected the results.

Blackberry From the four trials conducted in Victoria, there was no significant difference in the control of blackberry between Stinger and metsulfuron-methyl. In trial 113003GW at Blackwood, 748 days after application, Stinger gave residual control of broom (*Genista* sp.) that had germinated as a secondary weed in the plots compared to the untreated and metsulfuron-methyl alone plots, where there was no control of broom.

From the five trials conducted in New South Wales, Stinger gave significantly better control of blackberry in four out of five trials compared to metsulfuron, with the overall control with Stinger slightly less than that achieved in Victoria. In these trials, it was noticeable that black thistle (*Cirsium vulgare* (Savi) Ten.) did not occur as a secondary weed in the plots treated with Stinger.

Table 1. Comparison of Stinger vs metsulfuron for control of gorse, Australia, 20-23MAA.

Trial Number			113021GW	113022GW	123002GW	
Location			Carlsruhe	New Gisborne	Ballarat	
Spray Date			25-Nov-11	25-Nov-11	15-Mar-12	
Assessment (DAA)			712	712	601	
Product	**Rate (g /100 L)**	**Adjuvant**	**%REGROWTH SUPPRESSION**			**MEAN**
Stinger	30	Pulse	87	98	77	**87**
metsulfuron	15	Pulse	78	83	90	**84**
		LSD	23.6	16.5	10.4	
		CV	18.9	12.0	8.8	

Table 2. Comparison of Stinger vs metsulfuron for control of blackberry, NSW, Australia, 22-25MAA.

Trial Number			104014RA	112001CP	112004NE	112005NE	112004NE	
Location			Tenterfield	Tumbarumba	Armidale	Wallabadah	Armidale	
Spray Date			29-Apr-10	28-Feb-11	14-Mar-11	16-Mar-11	3-Jun-11	
Assessment (DAA)			685	769	758	756	677	
Product	**Rate (g /100 L)**	**Adjuvant**	**% REGROWTH SUPPRESSION**					**MEAN**
Stinger	20	BS1000	90	81	99	72	60	**80**
metsulfuron	10	BS1000	35	83	91	50	33	**58**
		LSD	15.3	5.0	2.8	13.3	17.9	
		CV	13.7	4.5	1.1	6.9	16.7	

Table 3. Comparison of Stinger vs metsulfuron for control of blackberry, Victoria, Australia, 18-20MAA.

Trial Number			113002GW	113003GW	123001GW	123003GW	
Location			Lindenow South	Blackwood	Pakenham	Trentham East	
Spray Date			16-Mar-11	18-Mar-11	15-Mar-12	19-Mar-12	
Assessment (DAA)			770	748	405	596	
Active Ingredient	**Rate (g /100 L)**	**Adjuvant**	**% Regrowth Suppression**				**MEAN**
Stinger	20	BS1000	95	77	95	98	**91**
metsulfuron	10	BS1000	100	75	93	93	**90**
		LSD	-	18.9	12.0	8.9	
		CV	-	17.7	8.4	6.4	

Overall, Stinger Herbicide gave better control of blackberry in New South Wales and similar control of blackberry and gorse in Victoria compared to metsulfuron alone with the added benefit of residual control of secondary weeds, including broom and thistles.

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Effects of spot herbicide applications for control of cane needle grass (*Nassella hyalina*) patches in non-arable situations

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Abstract Cane needle grass (*Nassella hyalina*) is a perennial exotic unpalatable weedy grass from South America threatening critically endangered indigenous grasslands within the proposed Western Grassland Reserve between Werribee and the You Yangs in Victoria. This trial examined dose response applications of spot herbicide treatments (glyphosate, flupropanate, flupropanate granules and fusilade) applied individually onto patches of cane needle grass at a field site near Werribee. Cane needle grass survival and damage assessments were made at one week, one month, three months, six months and 12 months following treatments. Herbicide effects and control options for cane needle grass are discussed.

INTRODUCTION

Nassella hyalina is a tufted, perennial grass indigenous to Argentina, southern Brazil and Uruguay (Caro 1966, Rosengurtt *et al.* 1970). In Argentina, it is a common species but is quite sparse, and is of only intermediate feed value. It occurs predominantly on fertile soil in variable situations and is also found in woodlands (Rosengurrt *et al.* 1970, M. Gardener pers. comm.). It forms a minor component of the 'flechillar' ('little darts' – pointy seeded species), so named due to the dominance of *Nassella, Piptochaetium* and *Aristida* species in the pampas grasslands of South America (Soriano *et al.* 1992). It is reportedly palatable to stock (Rosengurrt *et al.* 1970) and is regarded as producing reasonable fodder. At Ravenhall, in the outer western suburbs of Melbourne, it has been observed that when the existing pasture is of low quality, *N. hyalina* is grazed. However, it is preferentially avoided when more palatable pasture species such as *Themeda triandra* and various *Austrostipa* and *Austrodanthonia* species are present (V. Stajsic pers. obs.).

Nassella hyalina was introduced into Australia for experimental assessment of its capacity as a pasture grass (Commonwealth Plant Introductions – 1930, 1945, 1957 and 1959 and from United States Department of Agriculture sources from 1924–1972) (Cook and Dias 2006). Cuthbertson *et al.* (1955) noted that 'the tendency for *N. hyalina* to run freely to seed has led to strong and natural regeneration at Trangie, NSW, a character of real value to the environment'. Such observations suggest that *N. hyalina* naturalisation in Australia has resulted from its escape from one or more of these agricultural experimental introductions. A weed is a plant growing where it is not wanted, but the socio-politics of who is doing the 'wanting' is dynamic as are society's attitudes and understanding of the issues. Cook and Dias (2006) noted that *N. hyalina* was just one of 145,000 accessions and more than 8200 species brought into Australia for agricultural assessment over the past 70 years. It is ironic that *N. hyalina,* with invasive properties once thought of as 'of real value to the environment' is now listed as one of the 28 National Environment Weed Alert species (DSEWPC 2012). It has also been assessed as having the second highest weed risk score out of 51 non-native naturalised plant species considered as serious environmental weed threats to Australia (Weber and Panetta 2006).

The Victorian Government is in the process reserving 15,000 hectares of land, 'The Western Grassland Reserve' (WGR), to protect native grasslands in Melbourne's west. The WGR covers two large areas around Mt Cottrell and Little River south west of Werribee. The primary aim of the WGR will be nature conservation, in line with international standards for protected areas (Dudley 2008). The WGR is composed of a mixture of 'vegetation states' ranging from high quality grasslands through to environmentally poor fertilized pastures and cropping areas. This land is principally composed of farmland and land left vacant from previous urban growth speculation.

Nassella hyalina has been identified as serious weed threatening the WGR (Steve Sinclair personal communication). The majority of *Nassella hyalina* infestations in the WGR occur in rocky, non-arable situations making spot herbicide applications the most likely herbicide treatments to be employed by herbicide contractors. This trial tested effectiveness of a range of spot treatment herbicides for *N. hyalina* control. Flupropanate (Taskforce) is a residual herbicide registered for *N. hyalina* control and has been shown to provide 6 months to 2 years control of emerging stipoid grass seedlings after application depending on soil type. Flupropanate has now been made available in a granulated formulation and the manufacturer claims it may be less damaging to indigenous grassland species (Hamish Munro, Granular Products Pty Ltd. pers. comm.). Glyphosate is registered for control of other stipoid grasses including *Nassella trichotoma* and *N. neesiana.* It is a non-selective herbicide. Fusilade is registered under permit for control of *Nassella neesiana* in NSW. This herbicide could also be useful for control of *N. hyalina.* This paper outlines results of a herbicide trial to assess chemical control methods for *N. hyalina* control.

MATERIALS AND METHODS

The experiment was undertaken on a property approximately 5 km north of Werribee just off Ballan Road 37.82° South and 144.51° East. The property was formally a cattle grazed pasture composed predominately of annual rye grass but is now being managed for rehabilitation of indigenous grasslands. Numerous patches of *N. hyalina* are invading this mostly non arable property threatening the grassland rehabilitation process. Spot treatment applications were applied using 10 L 'Solo' backpack sprayers fitted with flat spray nozzles applying water at a rate of 1500 L/ha. The sprayers used a piston pump. All herbicides were applied to actively growing *N. hyalina* on 20th of May 2012 except the glyphosate 10 mL treatment which was applied on the 10th of May 2012. Weather conditions on the 20th of May was cool (14°C) with light winds. (All plants were sprayed until runoff using standard spot spraying procedures. All herbicide treatments are listed in the results section).

EXPERIMENTAL PROTOCOL

Seventy five individual patches of cane needle grass greater than 4 m^2 were tagged and their location recorded on an Ipad MotionX mapping system. Within each individual cane needle grass patch, five individual cane needle grass plants were tagged and uniquely numbered using a wire peg and a plastic numbered sheep tag. Sixteen herbicide treatments were individually applied to cane needle grass patches and replicated five times. 16 treatments × 5 replications = 80 individual cane needle grass patches treated and 400 individual cane needle grass plants tagged. Patches were treated sequentially from treatment 1 to treatment 15 for each of five replications. The 1.0 L glyphosate treatments were applied to five individual patches of cane needle grass on the 10th of May 2013.

The cane needle grass patches occurred over an area of approximately 5 ha.

For each individual cane needle grass patch treated with fluproponate granules, the patch size was calculated in sq m and the weight of granules required for the specified treatment was then weighed and placed into a 'Scotts' hand spreader for manual even application and spread evenly across the cane needle grass patch being treated.

Individual plants were assessed for damage with 0=healthy and a 9=dead. If new healthy shoots were observed on an individual plant it was classified as a score of 0.

Individual plants were assessed after two weeks, one month, three months and six months after treatment application.

RESULTS AND DISCUSSION

Fluazifop is a post emergence, foliar absorbed, translocated grass-selective herbicide with little residual action. It is used on a very wide range of broad leaved crops for control of annual and perennial grasses (The Herbiguide 2014). Cane needle grass showed very fast damage responses to this herbicide with all fluazifop treatments having damage scores of 7 or more at 14 DAT (Table 1). However, the majority of treated plants had recovered after 180 DAT with the dose response % control ranging from 4.4% for the 0.8 L to 52% for 2.0 L fluazifop treatments (Table 1).

Glyphosate is a post emergence, foliar absorbed, translocated, broad-spectrum herbicide with little residual action. Glyphosate's broad spectrum activity and short residual life makes it a popular herbicide for targeted (spot spray) weed control in environmentally sensitive areas. Glyphosate is regularly applied at a rate of 1 L/100 L within the WGR by herbicide contractors (Steve Sinclair Personal communication). In this current study, spot spray treatments below 1 L/100 L of glyphosate provided almost no control of cane needle grass infestations (Table 1).

Table 1. Herbicide control efficacy on cane needle grass (visual score 0 = no control, 9 = dead). Control scores were assessed at various days after treatment (DAT).

Herbicide	Product rate per 100 L water	Control score 14 DAT	Control score 28 DAT	Control score 92 DAT	Control score 181 DAT	% Control 181 DAT
Control	0	0	0	0	0	0
Flupropronate (745 g/L)	100 mL	0	0	0.5	2.0	22.7
Flupropronate (745 g/L)	200 mL	0	0.1	1.8	7.5	83.6
Flupropronate (745 g/L)	400 mL	0.1	0	2.2	7.3	81.3
Flupropronate (745 g/L)	800 mL	0	0.1	2.5	8.1	
Fluazifop	800 mL	7.0	7.7	7.0	0.4	4.4
Fluazifop	1.2 L	7.6	8.0	7.9	1.4	15.6
Fluazifop	1.6 L	7.1	8	7.9	2.4	26.7
Fluazifop	2.0 L	8.0	8.5	8.9	4.7	52.0
Glyphosate (450 g/L)	350 mL	0.1	0.6	0.7	0	0
Glyphosate (450 g/L)	700 mL	1.0	1.0	1.3	0	0
Glyphosate (450 g/L)	1.2 L	3.5	5.0	5.9	1.4	16.0

Table 2. Herbicide control efficacy of flupropanate granules on cane needle grass (visual score 0 = no control, 9 = dead). Control scores were assessed at various days after treatment (DAT).

Herbicide	Product rate g/m^2	Control score 14 DAT	Control score 28 DAT	Control score 92 DAT	Control score 181 DAT	% Control
Flupropronate (745 g/L) Granules	0.75	0	0	0.9	2.7	29.8
Flupropronate (745 g/L) Granules	1.5	0	0.2	1.7	7.4	81.8
Flupropronate (745 g/L) Granules	2.25	0	0	1.3	7.4	81.8

Table 3. Herbicide control efficacy of glyphosate (450 g/L) on cane needle grass (visual score 0 = no control, 9 = dead). Control scores were assessed at various days after treatment (DAT).

Herbicide	Product rate per 100 L water	Control score 28 DAT	Control score 92 DAT	Control score 181 DAT	% Control 181 DAT
Control	0	0	0	0	0
Herbicide	Product rate per 100 L water	Control score 38 DAT	Control score 102 DAT	Control score 191 DAT	% Control 191 DAT
Glyphosate (450 g/L)	1.0 L	7.2	8.04	1.44	16.0 g

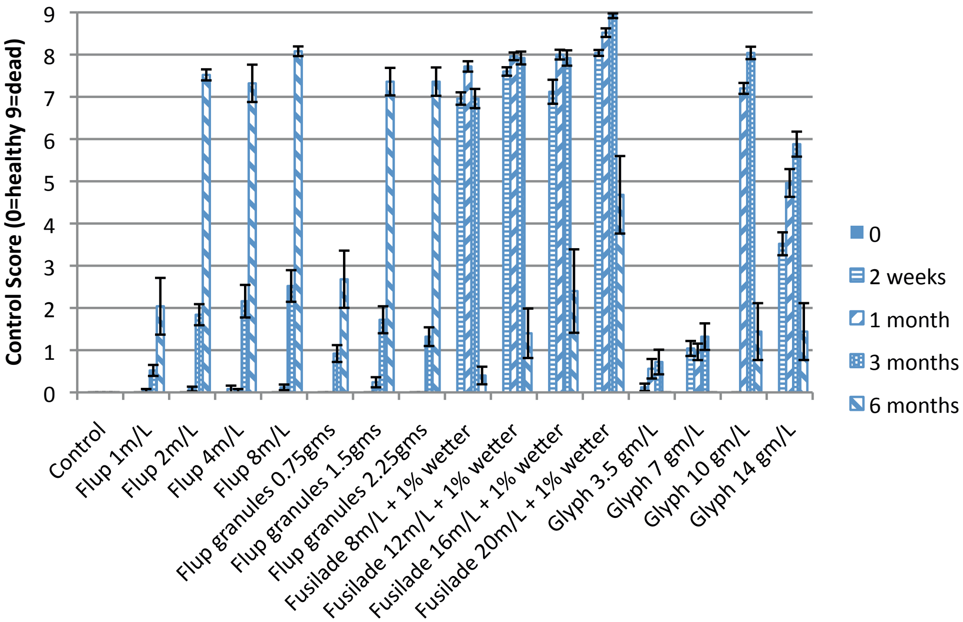

Figure 1. The rate response of three herbicides on cane needle grass control in a spot spray treatment trial.

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Disclaimer Further results are expected in May 2014 and a subsequent paper/s may be published in light of the new information. Please contact the author for further information.

To weed or not to weed? How Agent-Based Models are assisting in weed management and determining optimal and economic benefits of different control strategies

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Abstract Whilst economic models can calculate the costs and benefits of different weed management strategies, they have to assume a uniform rate of weed spread that is either under management or spreading without control. They do not take into consideration the heterogeneous nature of the landscape and the resulting differences in costs and benefits at specific locations.

Whilst land managers often report on the effectiveness of control programs in terms of the number of inspections and/or extent of area treated, rarely is there the ability to:

1. calculate the cost: benefit ratio of programs (the productive value of the area protected over time),
2. optimise the strategy by balancing costs with future benefits, or
3. allow for adaptive management scenarios.

To address these issues we have developed an agent-based weed dispersal model in NetLogo with in-built economic evaluation and management strategies components. A STELLA®-designed plant growth and dispersal model was converted into a spatially explicit NetLogo model with a dynamic interface to allow for 'on the fly' interactions with land managers. We are testing its performance on a real incursion in south-east Victoria and will use the validated model to project the spread of a weed over a ten year period. This will compare the costs and benefits of current control measures with a change in strategy to reflect either an increase or decrease in the funding of the weed's control.

The interactive nature of the model will allow land managers to visualize and calculate the effects of their decisions.

INTRODUCTION

One of the major issues of coordinated weed management across large and diverse landscapes is determining what is the best strategy given a limited or constrained budget. Trying to determine the strategy, the benefits and costs of the different options requires the involvement of a variety of participants (landholders, community groups, operational staff, researchers, policy and economists).

At a local spatial scale (i.e. at farm level) there is clearly good reason for landholders to control their own weeds to mitigate negative economic and environmental effects. For many weed species the impacts can immediately be observed by the landholder and this promotes self-motivation to manage the weed. This is particularly true for weeds of broadacre cropping where the competition between species is usually evident. For some weed species, however, the benefits of control are not apparent until the weed has reached a density or level of infestation that causes obvious impacts. For example, pasture weeds may be tolerated at a low level but at some point they reach a threshold that prompts a landholder response. Unfortunately by this stage a weed such as serrated tussock (*Nassella trichotoma* (Nees) Hack. ex Arechav.) is likely to have reached reproductive age and have spread to other properties over a number of years. Under this circumstance there is a role for government investment where there is a general public good in preventing further spread by ensuring landholders prevent the dispersal of the weed. Such actions from government incur a cost and in this case the cost equates with the number of times departmental Compliance Officers visit landholders to encourage or enforce control of the weed. There is a requirement for the government to quantify the benefits of serrated tussock containment. At present programme managers commonly report the area or number of infestations that were detected each year and what proportion were treated. Whilst this is a measure of achievement it falls short of evaluating the benefits of the programme in two important ways.

Firstly, the number of treated infestations does not directly indicate how effective the programme is at reducing the weed's spread. There is an assumption that the more infestations that are treated the slower the spread, but research suggests that it is more important to treat infestations in particular locations that are a major source of propagules than to maximize the number of infestations that are treated.

Secondly, if the species continues to spread this can give the impression that the programme is not effective. However, if the aim is to limit or slow the spread of the species then this is an unfair assessment. A more appropriate assessment would be to estimate the extent the weed could have spread without the programme and compare to this the area that was still infested at the time of reporting. This approach has the added benefit of being able to calculate the economic loss of productivity that could have occurred without the containment programme. This avoided loss allows us to calculate the benefit of the programme and compare this to its cost. Cost–benefit analyses can be used to compare the efficiency of different weed management strategies for a species, such as containment focused either on older core infestations or newer satellite infestations.

Economic models calculate the costs and benefits of different weed management strategies but they assume a uniform rate of weed spread (as illustrated in Figure 1) for a given scenario and do not take into consideration the heterogeneous nature of the landscape that affects spread rates. This heterogeneity results in different costs and benefits at specific spatial and temporal scales.

Computerised weed spread models combined with economic analysis can be used to integrate the interactions between weeds and their environments. Their outputs can be verified against field data to determine how accurately the modelled spread corresponds to the known historic spread. Importantly these models can also be used to spatially illustrate (i.e. on a map) the different results that each strategy is predicted to have. They show the user how far and where the weed is likely to spread without the control programme and compare predictions of spread under different types of control strategies, each with its own measure of cost.

We developed a weed dispersal model in NetLogo with in-built economic evaluation and management strategies components. A STELLA®-designed plant growth and dispersal model was converted into a spatially explicit NetLogo model with a dynamic interface to allow for "on the fly" interactions with land managers. We have tested its performance on a real incursion of serrated tussock in south-east Victoria and the model has been used to project the future (10 years) spread of the weed. This process will compare the costs and benefits of current control measures with a change in strategy to determine which programme could yield the greatest economic benefit.

The interactive nature of the model has the potential to allow land managers to visualise and calculate the effects of their weed management decisions.

METHODS

Model development The model consists of a number of modules that interact to simulate the spread of serrated tussock across a real-life landscape under different management scenarios, including:

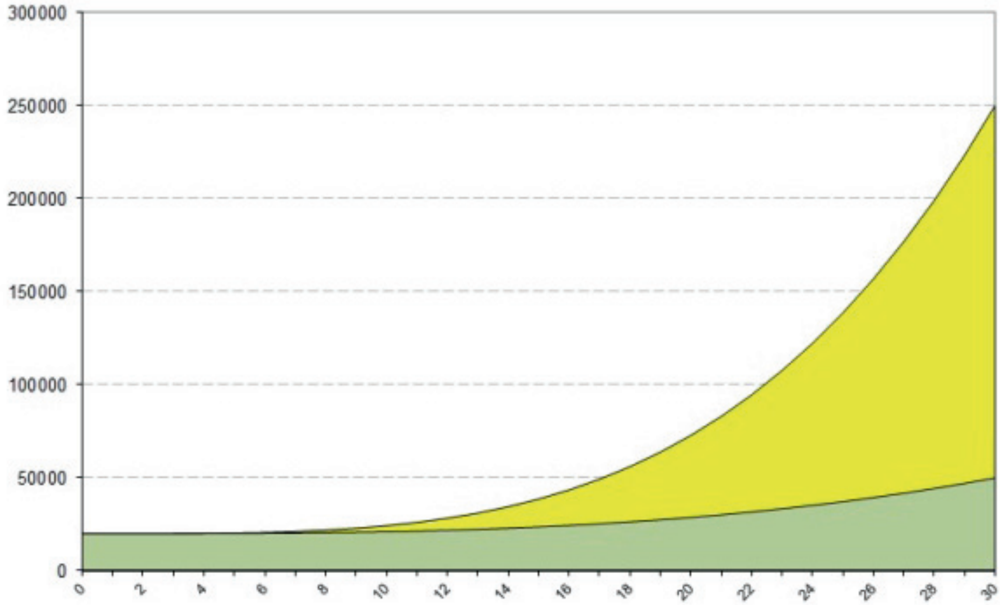
a) **serrated tussock life cycle** which grows each plant from seed to adult producing its own seeds;
b) **wind spread** module that disperses a proportion of these seeds across the landscape;
c) **landscape suitability** module that allows a certain number of seeds to germinate and progress through the life cycle, depending on the type of vegetation that is recorded at each location that receives the dispersed seeds, and how suitable it is for the establishment and growth of serrated tussock; and
d) **weed management** module that determines what proportion of landholders control serrated tussock on their land and how effective the control is.

The model operates across a realistic landscape that is divided in to 200 × 200 m cells. Each cell contains information that relates to each of the modules described above. So for any point in time (month) that the model is running, each cell contains a number of plants and/or seeds (or is not infested) at a certain stage of the life cycle (a), has a probability of seeds arriving from another cell via wind dispersal (b), comprises a land use that may or may not be suitable for serrated tussock (c), and is managed (or not) according to the settings in the management module (d).

The life cycle module was originally developed in STELLA® to operate within a single cell, but to enable the model to operate across a landscape we needed to also use an additional software tool, Spatial Modelling Environment. To streamline the model's operation we converted to using NetLogo, which operates directly in a spatial environment. The components of the life cycle module are summarized in Figure 2.

Published literature and expert opinion give a range of values for the maximum number of individuals at each stage of the life cycle that would be expected to occur within a unit area of an infestation. These figures were used to set up the life cycle module as annotated in Figure 2. However, serrated tussock does not survive well in shade (Healy 1945) so the landscape suitability module adjusts the maximum values in the lifecycle module so that the percentage of seeds germinating and the area that can be invaded

(a)



(b)

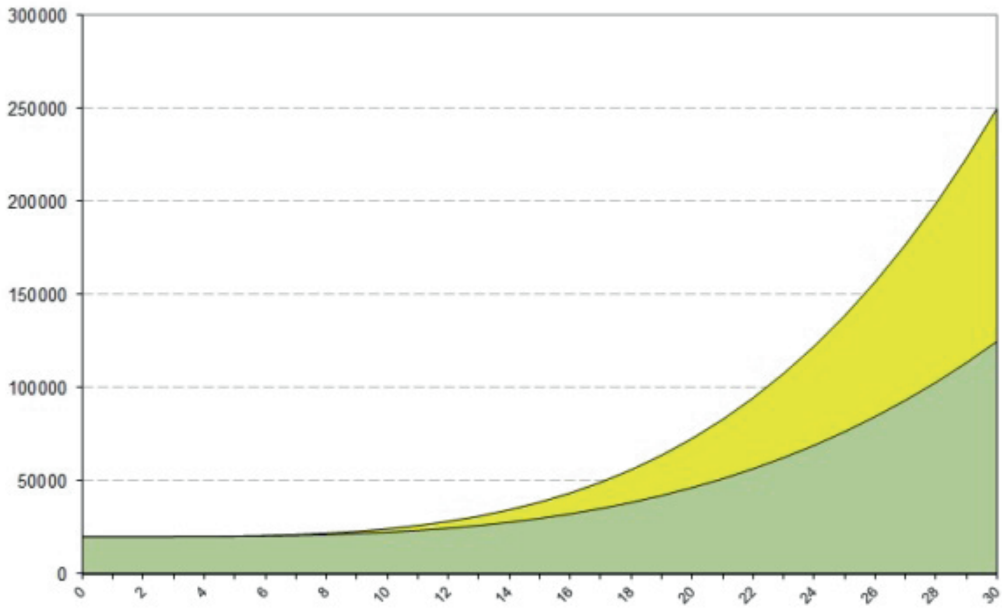


Figure 1. Models that estimate a uniform rate of spread can be used to calculate the area a weed could infest without inducing landowners to control it (yellow) and the area the weed could infest if compelling landholders to control it reduces its rate of spread (green). The benefit of government investment in weed control programmes is the difference between the two areas. (a) shows a greater benefit because the rate of spread under this management scenario is slower than (b).

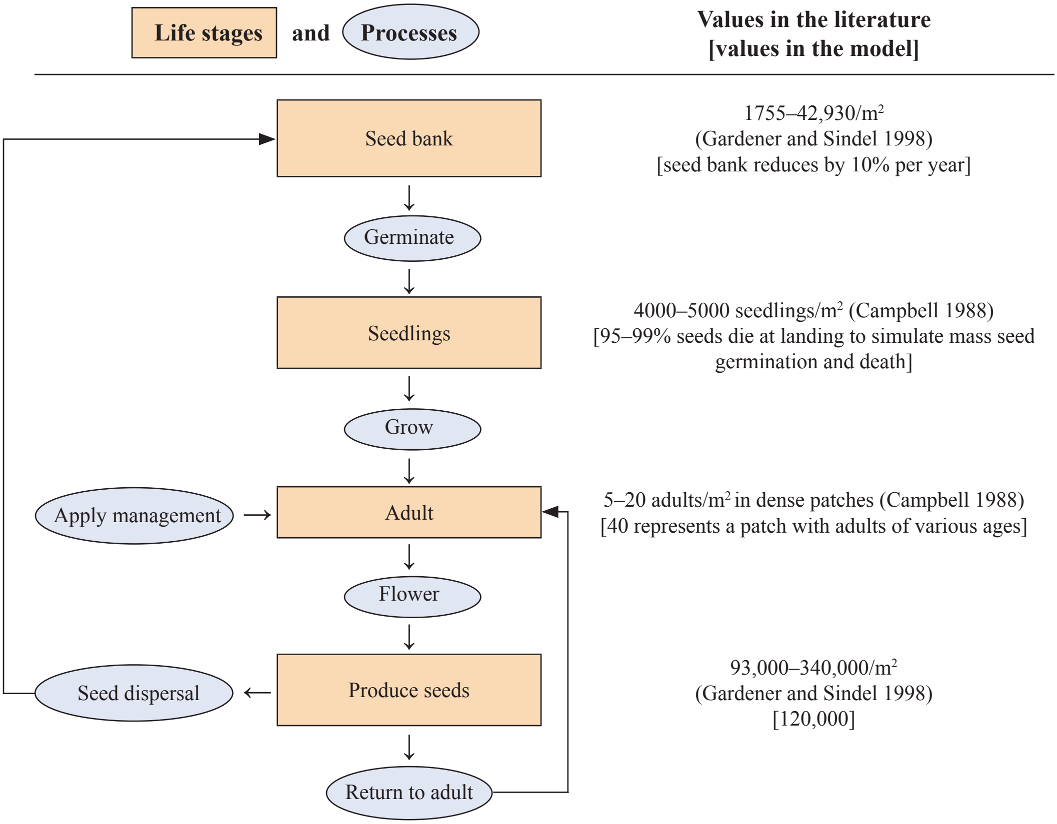


Figure 2. The lifecycle module. Individuals within a cell progress through each of the illustrated life stages (in rectangles) by undergoing each relevant process (in elipses). The number of individuals at each life stage that can occupy each cell is limited to within published values for this species. The specific values used in the model were chosen because they best simulated observed population dynamics over the operation of the model.

are linked to the type of vegetation that was recorded in each cell (see Table 1). The more canopy gaps in a vegetation type, the higher the proportion of serrated tussock plants can germinate and survive in each cell. For example, in irrigated pasture there would be very few canopy gaps at any particular time so only 1% of the maximum number of seeds that can germinate will do so each year the model runs (Table 1.) However, over time, 100% of the pasture could be occupied by serrated tussock. In perennial horticulture, by contrast, the model allows 5% of the available seedbank to germinate, but due to the permanent canopy cover of fruit trees the maximum area of the cell that could be infested with serrated tussock is only 20%.

This life cycle and landscape modules interact so that the number of adult plants that establish from germination of the seedbank (in the life cycle module) depends on the type of vegetation that is present in the cell (from the landscape module). In turn the number of seeds that are dispersed from the cell depends on the number of adult plants that develop and the direction and distance that the seeds disperse is determined by the wind module. The effect of the management module is that a proportion of the plants are killed (or not) depending on whether the landholder controls serrated tussock on their property and how well they can detect and treat the infestations. These effects are also summarized in Table 1.

Management strategies can be manipulated by using the model interface, illustrated in Figure 3. Zones can be drawn on the map for surveillance or control to occur in particular locations. The proportion of landholders that control serrated tussock on their property each year, and how effective their control efforts are can be chosen using slider bars (circled).

Model calibration The model was initialized with the earliest locations of the infestations that were recorded from the study area between 1988 and 1998 and the model was run for 14 years from 1998 to 2012. The spread predicted by the model was compared with the infestations recorded in the study area from 1988–2012. The operation of the model was adjusted so that the predicted spread most closely matched the recorded spread. This allows us to run the model from 2013 onwards with confidence that the model will forecast the spread of serrated tussock under a range of different management scenarios well.

RESULTS

The model predicts the spread of serrated tussock well in some parts of the study area where the infestations overlap the projected spread (Figure 4), but further calibration of the model is required to increase confidence in the model's outputs: reducing the area that is predicted to be infested but is not (reduce the false positives) and expanding the projected spread to encompass more of the recorded locations (reduce the false negatives).

In this paper we present the model's prediction of the future spread of serrated tussock under the management scenarios:

a) Do nothing – no more government intervention or investment; and
b) Containment I – Government intervention continues with current strategy. This approach requires compliance visits to every infested property.

Table 1. Model parameters associated with different land uses within the study area.

Name of land use (susceptible to serrated tussock invasion and present in the study area)	**% germination**	**% invasible**	**Management – effects and associated costs**
Broadacre cropping	5	5	Annual broadacre spray that kills all seedlings is common agricultural practise. No added cost to landowner or government.
Horticulture perennial	5	20	Variable percentage of land managers control ST due to voluntary compliance and enforced compliance. Cost to landholder of chemical. Cost to government of extension and education associated with specific levels of compliance.
Horticulture annual	5	5	
Pasture dryland	6	100	
Pasture irrigated	1	100	
Urban	10	15	Assume that mowing occurs without government intervention preventing long distance dispersal from these infestations
Native vegetation	1–6	46–100	Percentage of infestations that are treated is variable and can be from 0 to 100%. All cost to government.
Roadsides	*	*	All infestations are treated. All cost to government
Periurban	*	*	Infestations are not treated. No cost to government

*% germination and invasible area were scaled to the underlying land use for these areas.

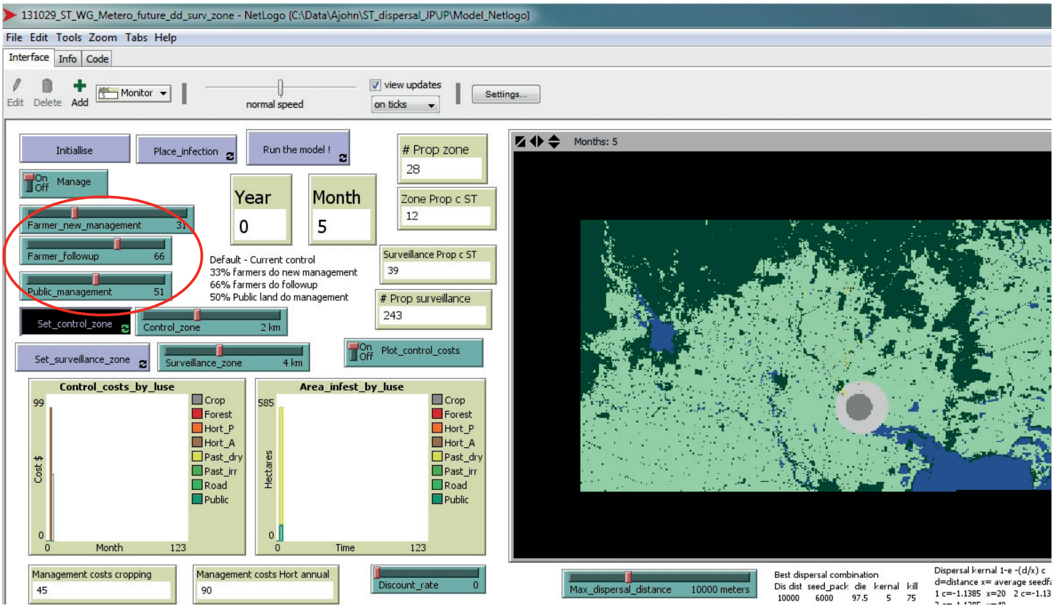


Figure 3. The user interface can be used to choose different values for some inputs. For example, Farmer-new-management, Farmer-followup and Public_management can range from 0–100% using the slider bars (circled).

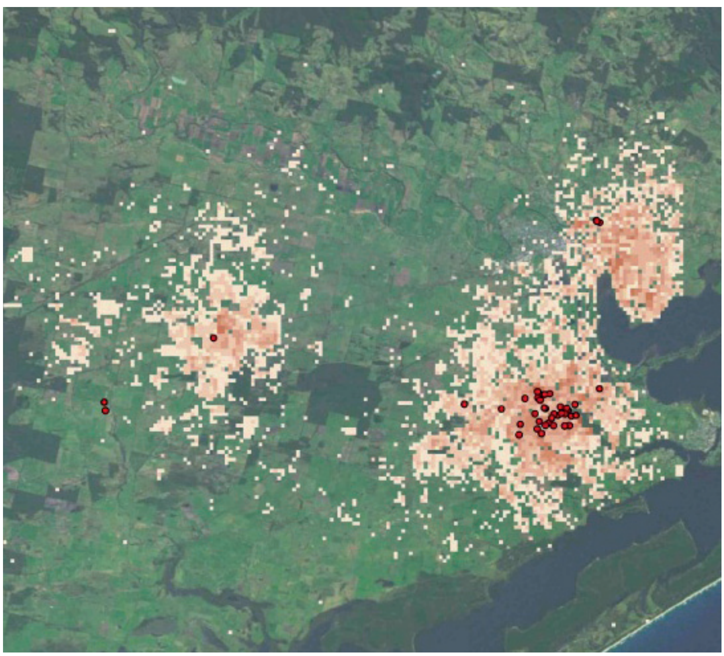


Figure 4. Area projected to be infested with serrated tussock by 2012 (brown shaded cells) compared to the recorded infestations in 2012 (red dots).

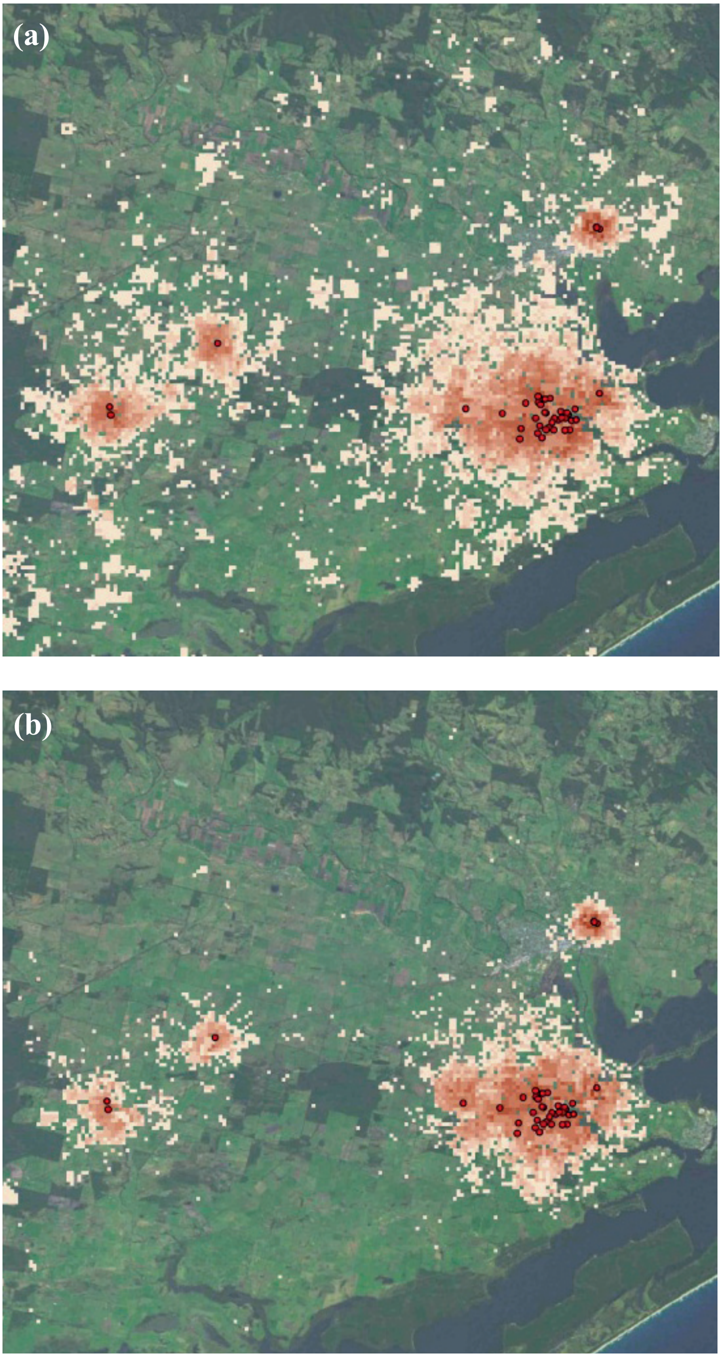


Figure 5. Area projected to be infested with serrated tussock (brown shaded cells) after 10 years under (a) the 'do nothing' management scenario and (b) the 'Containment I' management scenario. Red dots are recorded infestations in 2012.

FORECASTING

The model was first used to predict the spread of serrated tussock should the government reduce its investment to nothing (Figure 5a). It was assumed that some serrated tussock control would continue due to common agricultural practices and voluntary control by aware and concerned land managers. By comparison, a continuation of the current strategy (Containment I) is predicted to allow serrated tussock to spread less extensively as illustrated in Figure 5b. Serrated tussock has continued to spread under this strategy so if the budget for compliance remains the same, over time there will be a reduction in the proportion of properties that are visited each year which will diminish the effectiveness of the strategy as proportionally fewer land owners will be compelled to comply each year.

As well as measuring the number of hectares of infested land, in both native vegetation and on private property, the model also measures how many properties were managed by landholders and whether the management was due to voluntary control or compliance with government intervention. These figures will be used to determine the economic cost and benefits of these two different scenarios.

The Department of Environment and Primary Industries holds within its capability the expertise to develop weed spread models that can be used to quantify the costs and benefits of a range of realistic management scenarios utilising the following departmental resources:

- biological and ecological research on weeds,
- economic analysis capability,
- proficiency in designing weed control programs (including interface with landholders), and
- modelling expertise.

Future work will use the data that is output from the model (number and locations of infestations, types of management strategies and number of landowners controlling serrated tussock) to determine the cost–benefit of the strategies described in this paper, as well as:

a) Containment II – Government intervention will continue with the same budget but different strategic approaches will be tested using the model.
b) Eradication – the model will be used to provide an estimate of the cost of a programme of government intervention that results in eradication of the species from the study area.

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Managing biosecurity risk
Prioritisation of pest animals: lessons that can be learnt from the Australian Weed Risk experience

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Abstract How society manages the various risks posed by biosecurity is changing. This paper examines how risk assessment and prioritisation of pest animals is done across Australia. It seeks to compare and contrast these risk assessment and prioritisation systems with those used for weeds (pest plants). The lessons learnt from the application of Weed Risk Assessment and Management systems to pest plants might then be used to improve pest animal risk assessment and prioritisation.

The right plant in the right place: the management of contentious species to minimise the risk to native environments

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Summary Species which have a commercial value in agriculture may also have the potential to be weeds in native environments. The Future Farm Industries Cooperative Research Centre (FFI CRC) has developed the use of perennial plants to improve the productivity and profitability of agricultural systems. However, many of the characteristics that make a species a successful component of an agricultural system are the same as those that may make it a serious weed in native environments. This applies to species that are new introductions from outside Australia, introductions now naturalised or native species used in new environments. Risk assessment is an important component in the development of integrated strategies for the management of agricultural systems to minimise risk to native environments

An environmental weed risk strategy, developed within the FFI CRC, aims to minimise environmental risk when selecting and using perennial species. This framework includes an environmental risk policy, weed risk assessment, experimental guidelines and species management guides. A genetic risk assessment has also been developed to identify the risk of genetic invasiveness to natural populations from planted stands of species under evaluation within the CRC.

Keywords Risk assessment, weed risk, genetic risk, environmental weed.

INTRODUCTION

The risk that some introduced species pose to native environments has been well documented (Lonsdale 1994). Some of these species were introduced accidentally in packing material or as contaminants in other produce; some as garden plants, familiar to the incoming migrants, and some have been introduced as agriculturally useful species. It was estimated some time ago that Australia spends at least $20 million annually on the control of weeds in natural environments (Sinden *et al.* 2004). The potential for agricultural species to become environmental weeds is receiving increasing attention in the development of new farming systems, such as those that are a focus of the Future Farm Industries Cooperative Research Centre (FFI CRC). The FFI CRC aims to develop perennial species to improve the productivity and profitability of farming systems in southern Australia. These perennial species may be new introductions from outside Australia, species naturalised from previous introductions or native species now used in new environments or in novel ways in farming systems. However, the same characteristics that make a species a successful component of an agricultural system, such as drought tolerance or high biomass production, may also increase the risk of becoming a weed of native environments.

As part of fulfilling its legal responsibilities and acknowledging a duty of care, the FFI CRC has developed an Environmental risk strategy to help minimise the risk that agriculturally useful species might become weeds of native environments. The Environmental risk strategy has five core elements: an environmental risk policy, which defines compliance obligations (at border and post-border level) and outlines additional procedures for FFI CRC internal weed and genetic risk management; assessment protocols for weed risk (WRA) (Stone *et al.* 2008) and genetic risk (GRA) (Byrne *et al.* 2011); field trial guidelines for use when planning research trials and finally, Management guides, which provide information to help minimise environmental weed risk, for some species that have received high scores in FFI CRC WRA. The environmental risk strategy also raises awareness of the potential that agriculturally useful species can become environmental weeds with researchers, agriculturalists and the wider public.

ENVIRONMENTAL RISK STRATEGY

The environmental risk strategy provides a framework in which all the component parts are integrated to help minimise the risk of agriculturally useful species becoming environmental weeds.

The policy describes the identification and management of environmental risk as a multistage process that encompasses Federal and State obligations and an internal CRC process of risk assessment.

RISK ASSESSMENT

The FFI CRC WRA protocol follows a well established pattern (Pheloung *et al*. 1999; Standards Australia HB 294 2006) with sections addressing invasiveness and impact. Species may be new introductions to Australia, introductions now naturalised or native species that may be used outside their normal range. Information from a wide literature search is added to that from CRC researchers and other experts in the field. A map of the area of native environment potentially at risk, within each state in which the FFI CRC operates, forms the third component of the assessment. Scores are derived for Western Australia (below the tropic of Capricorn), South Australia, New South Wales and Victoria and range from Very High to Negligible. The FFI CRC does not promote species that are found to have a score of very high. Where a High score is recorded an alternative species should be sought or, if the benefits of using a particular species are considered to outweigh the risks, a Management Guide may be developed to provide further information for agriculturalists to minimise the risk to the environment.

The concept of genetic risk assessment (GRA) is less well known and here refers to the movement of foreign genes from domesticated or other non-local populations into native populations via pollen, and the potential for this to result in negative impacts to populations (Arnold 1992). The movement of genes between planted and native stands may result in hybridisation, where mating systems are compatible between species, differentiated taxa, cultivars or populations within species. This can have implications for the offspring of both the planted and native stands. The GRA protocol that has been developed is site specific and provides questions, in sequence, on the relevant taxonomy and biology of the species and the geographical context of the plantings. Low or negligible risk may be identified at a number of points so that the whole assessment may not need to be completed before an outcome is achieved. Further evaluation is required as a greater likelihood of risk is identified. The final, geographical section addresses the site specific criteria of the proposed planting and recommendations can be made for management actions to minimise the genetic risk where necessary.

Field trial guidelines and a checklist of key considerations when planning research evaluation have been developed. Risk assessments form part of this process and can be used to re-evaluate species selection or indicate areas in need of further research, which will in turn provide further information to update the assessment.

The weed and genetic risk protocols are available on the FFI CRC website along with the field trial guidelines and checklist. Species management guides are published as fact sheets and are also available at http://www.futurefarmonline.com.au/about/weedrisk.htm.

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FORUM
Putting the public interest into invasive species policy

Chaired by Andrew Cox, Invasive Species Council
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INTRODUCTION

Governments have an essential irreplaceable role in biosecurity to protect the public interest in the natural environment. State and federal governments are the only bodies with sufficient resources, coordinating ability and regulatory powers to oversee management of existing invasive species and to prevent new invasive species.

But when the fate of the natural environment is at stake, how does the public interest fare, particularly when there are competing interests? There are numerous examples in biosecurity of commercial or special interests prevailing over the public interest, often with only minor or replaceable advantages for the beneficiaries. It is frequently a default position, with no attempt to assess risks or do cost-benefit analyses when a decision is likely to be contentious. It is manifest also in the allocation of public resources and the priorities of government programs.

EXAMPLES OF THE PUBLIC INTEREST BEING IGNORED

The public interest has been given a low priority in cases such as the introduction and promotion of invasive pasture grasses, the unwillingness to prevent the nursery industry selling weeds or the aquarium industry selling invasive fish, the protection of feral deer for recreational hunting and generally weak post-border environmental biosecurity. It is also evident in the lack of resources dedicated to environmental biosecurity programs and research compared with those for industry.

There are two dedicated national bodies, Plant Health Australia and Animal Health Australia, tasked with contingency planning for potential pests and diseases that may impact on agriculture and other industries, supported annually with over two million dollars of public funds. Despite many more species that could potentially harm the natural environment, there is no environmental equivalent.

In Victoria tall wheat grass (*Lophopyrum ponticum*) was released, promoted and its use subsidised by the government as a salinity tolerant pasture grass. It has escaped cultivation at hundreds of sites, and according to a state government assessment, it could invade more than 10 million hectares of Victoria. Despite its listing as a potentially threatening species under the Flora and Fauna Guarantee Act, the government has continued to promote its planting. The department promoting it is also in charge of weed declarations.

A specialist nursery on Melbourne's outskirts sells a large variety of *Oxalis* species that it promotes as 'wonder plants'. Sour sob (*Oxalis pes-caprae*) has become a widespread weed in Victoria and NSW and declared a noxious weed in both states but the sale of other *Oxalis* species with similar weedy characteristics is permitted. This pattern of inconsistency and permissiveness results from lack of a systematic process to consider the public interest in decisions (or non-decisions) about introduced species.

GUARANTEEING THE PUBLIC INTEREST

There are substantial institutional and regulatory changes needed to ensure the public interest in the environment is accorded appropriate priority in biosecurity. We highlight three changes here. The Invasive Species Council has observed that the public interest is better served where there is a statutory requirement for risks to be systematically considered, such as is the case for importing new species into Australia. Secondly, there is need for a methodology to cost the impacts on the environment from invasive species. Thirdly, decision-making on environmental biosecurity needs to rest primarily with the ministers and officials who are primarily responsible for environmental protection rather than with agricultural departments who often have a conflict between their industry promotion and biosecurity roles.

FORUM QUESTIONS

This forum seeks to explore the crux challenge – how do we achieve the reforms needed to place the public interest at the centre of invasive species policy and management?

The forum will discuss the following questions:

Barriers

1. What examples relating to invasive species (weeds, feral animals and other pests) have you come across where minor or special interests have prevented action in the public interest? What were the barriers to action and how could these be overcome?

2. The permitted list approach (limiting the sale and movement of all but low weed-risk plants) is seen as the most important mechanism for preventing the introduction of new weeds into the wild. What are the barriers to embrace a permitted list approach in Victoria?

Overcoming barriers

1. How can we better make a more compelling case for the public interest in the environment to be a primary consideration in biosecurity policies and decision-making, and prevent it being routinely over-ridden by special or commercial interests?

2. How do we build the political appetite for reform?

3. What is the role for non-government organisations, such as the Australian Conservation Foundation, the Invasive Species Council and the Weed Society of Victoria?

4. What is the role of weed experts?

Weed Society of Victoria Inc.

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