

19th NSW Biennial Weeds Conference Papers

Experience the Highs – working smarter together



16 – 19 October 2017
Armidale NSW



Department of
Primary Industries



CONFERENCE PAPERS

Instructions: Click on paper name to proceed directly to page.
Press Shift+Ctrl+Up Arrow to return to contents page

CONTENTS

1. ARE AUSTRALIAN LAND MANAGERS MEETING THE CHALLENGES OF HERBICIDE RESISTANCE IN THEIR WEED MANAGEMENT SYSTEMS?. 5

Andrew Storrie

2. PUTTING THE “WE” BACK INTO WEEDS 11

Professor Paul Martin

3. CHAIN, CHAIN, CHANGE – PART ONE 18

Applying a behaviour change framework to tropical soda apple control in NSW - insights from the North Coast.....

Elissa Van Oosterhout & Professor Paul Martin

4. CHAIN, CHAIN, CHANGE – PART TWO	23
Applying a behaviour change framework to lantana control in NSW - insights from the Far South Coast.....	

Elissa Van Oosterhout & Professor Paul Martin

5. A COMMUNITY BASED SOCIAL MARKETING APPROACH TO SERRATED TUSsock MANAGEMENT	29
Lessons from the Snowy River Region.....	

Simon Mulvaney

6. RETHINKING COMMUNITY ENGAGEMENT APPROACHES: SYSTEM-STRENGTHENING FOR INVASIVE SPECIES MANAGEMENT	34
--	-----------

Tanya Howard

7. AN INCONVENIENT TRUTH	39
Weeds in urban landscapes	

Wendy Bushell

8. COMBATTING GLYPHOSATE RESISTANT WEEDS ALONG FENCE LINES AND ROADSIDES	41
---	-----------

Tony Cook & Bill Davidson

9. POST FLOOD SURVEILANCE FOR AQUATIC WEEDS THE HOW, WHY, AND WHEN	53
---	-----------

Charlie Mifsud

10. ILLEGAL ONLINE TRADE OF NOXIOUS WEEDS IN AUSTRALIA: MONITORING AND REGULATING E-COMMERCE	58
---	-----------

Zachariah Munkamwe & Angela Constantine

11. EDUCATION ENFORCEMENT AT THE FLEMINGTON FLOWER MARKETS, SYDNEY	63
---	-----------

Emily McCarthy

12. PUBLIC AWARENESS: BUILDING WEED AWARENESS IN THE COMMUNITY	68
---	-----------

Karen Jenkin

13. REARING BIOLOGICAL AGENTS FOR CONTROLLING THREE WEED SPECIES IN NSW..... 76
Update on the biocontrol agent rearing and release program at the Grafton Primary Industries Institute

Troy Brown

14. SPREAD OF INVASIVE GRASSES INTO NAMADGI NATIONAL PARK 81

Steve Taylor et al

15. WATER HYACINTH MAPPING IN GWYDIR WETLANDS USING REMOTE SENSING TECHNIQUES..... 87

Rajenda Shilpakar et al

16. BEGINNING A NEW ERA..... 92

Peter Scott

17. REGIONAL JOINT PROJECT COLLABORATION 99

Mel Wilkerson

18. ALLOCATING RESOURCES TO MANAGE INVASIVE PLANT ERADICATION PROGRAMS..... 112

Oscar Cacho et al

19. FIRE AND WEEDS – WHO’S TALKING? 119

Mark Graham et al

20. COLLABORATION, COOPERATION AND TEAMWORK TO IMPROVE THE CONDITION OF BIODIVERSITY ASSETS IN THE NORTH WEST... 124

Peter Dawson

21. PLANT SURE: AN ENVIRONMENTALLY SAFE ORNAMENTAL PLANT SCHEME 128

Stephen B Johnson & Hillary Cherry

22. UAVS ANOTHER TOOL FOR THE WEED CONTROLLER..... 138

Phil Milling

23. DEVELOPING A PORTABLE DNA-BASED PLATFORM FOR RAPID ON-SITE IDENTIFICATION OF CHILEAN NEEDLE GRASS AND SERRATED TUSSOCK..... 145

LAMP diagnostics of invasive stipoid grasses

David Gopurenko et al

24. GREATER SAFETY AND EFFICIENCY THROUGH USE OF IMPROVED REMOTE REWIND HOSE REELS..... 152

Daniel Firth

25. A NEW PERMIT FOR AQUATIC WEED CONTROL: SHARK AQUATIC HERBICIDE – BROADENING CURRENT LABEL CLAIMS 165

Tony Cook

26. HIGH RISK WEEDS STUDY TOUR..... 173

Roger Smith & Mick Ryan

27. GETTING A GRIP ON THE SLIPPERY SICILIAN SEA LAVENDER LIMONIUM HYBLAEUM..... 158

Stephen B. Johnson

28. EXTINGUISHING THE FLAME – FIREWEED CONTAINMENT IN THE ACT 176

Jenny Conolly & Steve Taylor

ARE AUSTRALIAN LAND MANAGERS MEETING THE CHALLENGES OF HERBICIDE RESISTANCE IN THEIR WEED MANAGEMENT SYSTEMS?

Andrew Storrie

AGRONOMO, PO Box 5944, Albany, WA 6332
Executive Officer, Australian Glyphosate Sustainability Working Group
andrew@agronomo.com.au

ABSTRACT Glyphosate is the world's most widely used herbicide with global use exceeding 850 thousand tonnes in 2015. Western agricultural systems have become increasingly reliant on glyphosate as it has enabled the widespread adoption of reduced or no-tillage farming systems as well the continued widespread adoption of glyphosate resistant crops. These systems have environmental benefits of reduced soil erosion and fuel consumption, with production benefits of lower labour and capital costs, and higher and more reliable crop yield through improved stored soil water.

The development of weeds with resistance to glyphosate has paralleled the increasing reliance on this herbicide. Currently there are 37 species that have developed resistance to glyphosate, of which Australia has 15.

While most glyphosate resistance has been confirmed in agricultural environments, the number of populations being found in non-agricultural land use is increasing. In Australia, most broadacre farmers have been exposed to the herbicide resistance management message for over 30 years while land managers in the non-crop sector appear to have generally low levels of awareness of herbicide resistance and the problems it poses for landscape management.

While a 2011-12 national study of glyphosate use practices in the non-agricultural sector found little awareness of the issues current evidence suggests little has changed in the last 5 years. Key targets for many weed management decision-makers are based on cost and risk aversion. This paper discusses current direction of the development of herbicide resistance and suggests appropriate awareness and extension programs for non-agricultural users of herbicides.

Key words: glyphosate, herbicide resistance, non-crop, lineal reserve, roadside, railway, irrigation channel, non-agricultural, weeds

INTRODUCTION

Glyphosate is the world's most widely used herbicide with annual sales estimated at over \$US 6 billion. In 2016 it is estimated that 186 million hectares of genetically modified crops grown in the world (James 2017) with a significant proportion being herbicide resistant. Glyphosate is also widely used in other sectors including native vegetation rehabilitation, residential yards, parks and gardens, industrial premises, roadsides, rail lines and forestry. Its popularity is due to low cost, the number of species it controls, low odour, little soil activity and has low mammalian toxicity.

The wide usage of glyphosate in Australia is reflected by registration of 557 products containing glyphosate with nearly 40,000 registered uses (Infopest 2017).

Heavy reliance on any herbicide leads to the selection of both weed populations that are resistant or tolerant to that herbicide mode of action (Storrie 2014). Outside of agricultural uses, roadsides are one of the highest risk areas for selecting herbicide resistant or tolerant weeds due to the repeated use of herbicide with few non-herbicide control strategies being used to prevent the seed set of any spray survivors.

This paper will update the current world and Australian development of glyphosate resistant weed populations and discuss alternatives to current use patterns with particular emphasis on roadsides. The paper also explores the possibility of applying an awareness strategy used in weed biosecurity on intractable roadside weeds.

Current state of glyphosate resistance in the world

At the time of writing there are now 37 weed species in 27 countries confirmed to have resistant populations globally (Heap 2017). This is a doubling since 2011.

The concerning and growing complication is that at least one quarter of these populations are also resistant to one or more other herbicide modes of action. Australia holds the record with 5 modes of action in populations of annual ryegrass (*Lolium rigidum* Gaudin) and winter grass (*Poa annua* L.).

Resistance to multiple modes of action increases the difficulty of effective chemical weed control. It results from using a number of different herbicide modes of action without managing the seed set of spray survivors.

In the last 6 years some countries have had large increases in the number of resistant species while other countries have had no or little increase (Table 1). The countries with large increases also have widespread adoption of glyphosate resistant crops. Australia's tripling in the number of species largely comes from our widespread adoption of no-till crops with a concurrent decline in cultivation for weed control. This is in combination with extensive use of fallow between crops kept clean of weeds by repeated use of glyphosate (Storrie 2014).

Table 1. Change in number of species with populations resistant to glyphosate between 2011 and 2017 for a selected range of countries. (Heap 2017)

Country	Number of species		Country	Number of species	
	2011	2017		2011	2017
USA	11	15	Australia	5	15
Canada	1	7	Czech Republic	1	1
Brazil	5	11	Israel	1	2
Argentina	3	10	South Africa	3	3
Chile	1	1	China	1	2
Spain	5	5	Malaysia	1	2
France	1	2	Italy	1	3

There is a growing problem with the increasing resistance to other knockdown herbicides such as paraquat (Group L), glufosinate (Group N) and amitrole (Group Q). To date Australia has 10 species with Group L resistance while globally three species have glufosinate resistant populations and all but one have resistance to 2, 3 or 4 modes of action. Six species around the world have resistance to amitrole, including annual ryegrass in Australia, with half being resistant to 2 or 3 modes of action.

Glyphosate resistance in Australia

At the time of writing there are 15 species with populations confirmed resistant to glyphosate (Preston 2017).

Table 2. Species confirmed resistant to glyphosate in Australia (Preston 2017)

Weed species	Year first documented	Number of confirmed populations
Annual ryegrass (<i>Lolium rigidum</i>)	1996	678
Barnyard grass (<i>Echinochloa colona</i>)	2007	102
Liverseed grass (<i>Urochloa panicoides</i>)	2008	4
Flaxleaf Fleabane (<i>Conyza bonariensis</i>)	2010	65
Windmill grass (<i>Chloris truncata</i>)	2010	11
Great brome (<i>Bromus diandrus</i>)	2011	5
Tall Fleabane (<i>Conyza sumatrensis</i>)	2012	10
Wild radish (<i>Raphanus raphanistrum</i>)	2013	2
Sowthistle (<i>Sonchus oleraceus</i>)	2014	23
Red brome (<i>Bromus rubens</i>)	2014	1
Sweet summer grass (<i>Moorochloa eruciformis</i>)	2014	1
Prickly lettuce (<i>Lactuca serriola</i>)	2014	1
Feathertop Rhodes grass (<i>Chloris virgata</i>)	2015	4
Tridax daisy (<i>Tridax procumbens</i>)	2016	1
Winter grass (<i>Poa annua</i>)	2017	3

Many of these populations have been selected in broadacre cropping or related areas such as around buildings and along irrigation channels. However annual ryegrass, flaxleaf fleabane (*Conyza bonariensis* (L.) Cronquist), tall fleabane (*Conyza sumatrensis* (Retz.) E. Walker), windmill grass (*Chloris truncata* R.Br.) and feathertop Rhodes grass (*Chloris virgata* Sw.) are becoming significant roadside problems.

The problem with roadsides

Australia has nearly 800,000 km of roads (Anon 1987) that are at risk of developing weeds with resistance to glyphosate. Road safety and infrastructure maintenance are the key drivers for weed control. Roadsides must have clear lines-of-site around and up to posts and signs and the allowable distance will vary with the allowed speed limit. Often there is a 30 cm maximum height for roadside vegetation. Road edges or shoulders are also managed to keep them clear of vegetation to minimise movement of water under the 'seal' or into the road-base to minimise pot-holing and increased maintenance costs (Storrie et al 2012). The two main methods of vegetation management are slashing and spraying.

Slashing is slow and often requires several staff to alert motorists to the tractor and slasher ahead. In wet years and in higher rainfall areas it is difficult keeping vegetation at the allowable height. The design of many slashers also makes it difficult to prevent weed seed spread without significant down-time for cleaning. Most slashers are not able to get close to roadside furniture. Some managers deal with this by spraying around posts and roadside furniture (furniture is defined by those in the industry as objects such guide posts, bus shelters, traffic lights, road signs, armco etc).

Spraying the road shoulder is now the major form of vegetation management outside town boundaries. The width of the sprayed area varies from 1 to 5 m (Storrie et al 2012). Glyphosate is the main herbicide. Tank-mixing with another herbicide mode of action is often used to broaden the range of weeds controlled. The use of tank-mix partners, if any, will vary greatly depending on the management authority and state legislation.

The number of glyphosate applications in a year is usually determined by use situation and rainfall. Drier areas normally have 1 to 2 glyphosate applications per year, whereas wetter areas range from 1 to 5 applications. In most environments spring is the key spray time, while summer spraying is dependent on summer rainfall (Storrie et al 2012).

Market research has found most non-agricultural land managers are ill prepared to deal with glyphosate resistance and found that many councils would only use glyphosate for simplicity, safety and cost. Field staff and contractors wanted training, but this wasn't mirrored by management (Storrie et al 2012).

The threat of herbicide resistance is rarely mentioned in weed management plans by authorities involved with roadside management. Roadside weed management still concentrates on managing remnant vegetation, declared weeds and Weeds of National Significance (WONS).

A 2011-12 project on non-agricultural glyphosate use in Australia included a physical survey that targeted four weed species - annual ryegrass, fleabane, windmill grass, and awnless barnyard grass. Half the annual ryegrass and fleabane samples were resistant to glyphosate as were a smaller number of windmill grass populations. The majority of resistant samples came from roadsides (Malone et al 2012).

Glyphosate tolerant weeds are also becoming an increasing roadside problem. Glyphosate tolerant weeds are those that have never been easily controlled with glyphosate and include *Hyparrhenia* species (e.g. Coolatai grass), African lovegrass (*Eragrostis curvula* (Schrad.) Nees), Crownbeard (*Verbesina encelioides* (Cav.) A.Gray subsp. *Encelioides*), stinkwort (*Dittrichia graveolens* (L.) Greuter) and dove weed (*Croton setiger* Hook.).

Failure to manage for glyphosate resistance on roadsides is well demonstrated by the South Australian experience. In the early 2000's the South Australian government decided that only glyphosate would be used on roadsides for worker safety and environmental reasons. In 2011 irate farmer organisations brought the widespread infestations of glyphosate resistant annual ryegrass to the attention of the Department of Planning, Transport & Infrastructure SA. Farmers were concerned glyphosate resistant weeds would spread from roadsides into their paddocks. A state-wide management plan was quickly developed to halt the problem. Infestations are mapped and get additional treatments.

How do we stop hard-to-control weeds on road verges?

The best option is to proactively implement monitoring and management systems to identify and deal with hard-to-control weeds.

There is ample evidence of increasing incidence of both glyphosate resistant and glyphosate tolerant weeds on roadsides, however little proactive management takes place with roadside managers remaining unaware of resistance or give it a low priority (Congreve *et al* 2012).

For change to occur contractors, field staff and managers need to understand the threat and cascading effects resulting from hard-to-control weeds. Many authorities have already started mapping roadside vegetation so it is only a small step to map glyphosate resistant and tolerant weeds.

Also resistance management must be fairly included in agreements with contractors. They cannot bear the cost of additional management.

Resistance management messages need to be framed in positive terms to managers and field staff (Howie 2017). Messaging to get managers "on-board" might include:

- Cheaper overall weed management – monitoring and mapping of problem weeds allows site specific programs to be used, rather than treat all roadsides with more expensive strategies.
- Better relationships with ratepayers / Councillors. Spread of glyphosate resistant or tolerant weeds into farmers' paddocks usually creates conflict.
- Well trained and involved staff will be happier and work more efficiently.

A great start to the management of these weeds would be a modification of the "Red guide post program" (Bosse 2017). This project aimed to increase awareness of declared weeds

on roadsides and was supported by a well-planned extension campaign that included a wide range of pathways targeting all road users and managers.

Using a similar strategy for resistant and tolerant roadside weeds would increase adoption of better weed management while reducing the spread of these weeds and limit management costs.

ACKNOWLEDGEMENTS

The author would like to thank the RIRDC for having the foresight to fund Project PRJ-006914 - *Management of glyphosate resistance in non-agricultural areas*

REFERENCES

- Anon (1987) Assessment of the Australian Road System: 1987. Bureau of Transport Economics. Online. https://bitre.gov.au/publications/1987/files/report_061.pdf (accessed 20 July 2017)
- Anon (2017) Final Regulatory position: Consideration of the evidence for a formal reconsideration of glyphosate. Australian Pesticides & Veterinary Medicines Authority, Canberra, ACT.
- Bosse, P. (2017) Red Guide Posts – a weed awareness tool! (Riverina Regional Weed Committee: Albury, Australia). <http://www.riverinaweeds.org.au/rgp/> (accessed 20 July 2017)
- Congreve, M., Storrie, A.M., Cameron AJ (2012) Glyphosate resistance in non-agricultural areas - NSW, Victoria, South Australia & WA - Market survey report - RIRDC PRJ-006914. Rural Industries Research & Development Corporation, Canberra, ACT.
- Heap, I. (2017) International Survey of Herbicide Resistant Weeds. <http://www.weedscience.org> (accessed July 18, 2017)
- Malone, J., Cook, T., Wu, H., Hashem, A., Boutsalis, P. and Preston, C. (2012) Glyphosate resistance in non-cropping areas of Australia. In 'Giving a RATS' Issue 1 – autumn 2012 p. 7. <http://www.agronomo.com.au/giving-a-rats/>
- Preston, C. (2017) The Australian Glyphosate Sustainability Working Group. <http://www.glyphosateresistance.org.au/> (accessed 21 Jul 2017)
- Storrie, A.M., Cameron, A.J. and Congreve, M. (2012) Glyphosate resistance in roads and rail – how prepared are we? In 'Giving a RATS' – Issue 2 winter 2012 p. 4-7. Online <http://www.agronomo.com.au/giving-a-rats/>
- Storrie, A.M. ed (2014). "Integrated weed management manual for Australian Cropping Systems," 2nd Edition. Grains Research & Development Corporation, Canberra, Australia.

PUTTING THE “WE” BACK INTO WEEDS

Professor Paul Martin,

Director, Australian Centre for Agriculture and Law,
University of New England

Paul.Martin@une.edu.au

SUMMARY: What I am presenting is supported by empirical institutional and social research that I and my fellow researchers through the AgLaw Centre and the Invasive Animals CRC have carried out over the last decade, particularly over the last 5 years. The goal of all this work has been to answer one question: “what does Australia need to do to make its laws and other governance arrangements for the control of invasive plants and animals effective, efficient and fair?” For those of you interested in the rationale and evidence, I have provided a list of the publications that support the views I will present. Parts of this conference paper are drawn from these publications.

Keywords: Weeds, institutions, law, politics, funding

The social-environmental-economic challenge of weeds

Australia’s national strategy identifies the main causes of biodiversity decline as: invasive species; natural resource use and management; deterioration in the aquatic environment and water flows; fire; and climate change.¹ Of the 21 “key threatening processes” identified in Australia’s biodiversity strategy, 16 involve invasive species.² Invasive species also cause significant economic loss, particularly to farming enterprises; for example, the estimated annual losses for rabbits is \$206 million; \$48.5 million for wild dogs; \$21.2 million for foxes; and \$100 million for feral pigs.³ Invasive species also pose other health and welfare risks, such as the potential to spread disease or cause other human harms.⁴

A lot of effort and investment goes into invasive species management but is this sufficient to achieve the improvement contemplated under any of the many strategies? In relation to invasive species the recent State of Environment report on land management identifies that weed impacts are high, with increasing trend, summarising that

Invasive species—pests, diseases and weeds—threaten agriculture and forestry, native species, natural regeneration and ecosystem resilience. They already have a massive environmental, social and economic impact, and climate change is likely to enable new invasive species to thrive⁵

¹ National Biodiversity Strategy Review Task Group, Australia’s Biodiversity Conservation Strategy 2010-2030

² Department of Environment and Energy, Species Profile and Threats Database – Listed Key Threatening Processes

³ Wendy Gong et al, The Economic Impacts of Vertebrate Pests in Australia.

⁴ For example, by rodents, or the risk of the introduction of rabies into Australia.

⁵ Metcalfe DJ & Bui EN (2017). Australia state of the environment 2016: land, independent report to the Australian Government Minister for the Environment and Energy, Australian Government Department of the Environment and Energy, Canberra. Page v

And, within the biodiversity management assessment, as having an increasing and very high impact, summarised as

Impacts of invasive species have increased in importance as key threatening processes at both national and state/territory levels. The general consensus is that the impact of invasive species is not diminishing and, in combination with other stressors, may be increasing. Natural resource managers consistently identify a lack of resources for managing invasive species as a key impediment to successful management.⁶

The need to tackle the ‘we’

The ways invasive species enter, become established and expand involve many people. Control and rehabilitation efforts also involve many people to carry out preventative biosecurity, eradication or control, landcare or other environmental action, and landholder action. Government efforts are only a part of a complex system. The engagement of private citizens largely determines whether or not policy is effective.⁷

It is typically more efficient for citizens to detect and intervene directly than for government to do so. There are also not enough public resources to do the on-ground work, and governments lack the legal power or capacity to force citizens to carry out ongoing work on private lands. *Australia’s Biodiversity Conservation Strategy 2010-2030* emphasises community engagement is as its first priority.⁸ This emphasis is also found in the invasive species management strategies of most Australian States, and nationally.⁹

Australian government’s aim to limit their role to the preventative end of the invasion spectrum as much as possible. The rhetoric of “shared responsibility” asserts that industry and private citizens have the primary obligation to control established weeds and to report new incursions.¹⁰ This policy is accompanied by refocusing public resources away from the control of established invasive species. However, there is no strategy or consensus about how to increase private investment or otherwise to fill the private/public funding gap.¹¹

⁶ Cresswell ID & Murphy HT (2017). *Australia state of the environment 2016: biodiversity*, independent report to the Australian Government Minister for the Environment and Energy, Australian Government Department of the Environment and Energy, Canberra. Pvi

⁷ In the invasive species context, “shared responsibility” is recognised as essential to manage (particularly) already established species. See, e.g. National Biosecurity Committee, Department of Agriculture, *Modernising Australia’s Approach to Managing Established Pests and Diseases of National Significance*, Discussion Paper (2015)

⁸ The stated priorities in Australia’s Biodiversity Conservation Strategy being: (1) engaging all Australians; (2) ecosystem resilience; and (3) measurable results.

⁹ See, e.g. Department of Environment and Climate Change, *A New Biodiversity Strategy for New South Wales*, Discussion Paper (2008); Vertebrate Pest Committee, *Australian Pest Animal Strategy – A National Strategy for the Management of Vertebrate Pest Animals in Australia* (2007); Department of Primary Industry and Resources, *Northern Territory Biosecurity Strategy 2016-2026* (2016)

¹⁰ Senate Environment and Communications References Committee, *Environmental Biosecurity* (May 2015).

¹¹ W. Craik, D. Palmer, and R. Sheldrake, “Priorities for Australia’s biosecurity system, An independent review of the capacity of the national biosecurity system and its underpinning Intergovernmental Agreement,” Canberra ACT, 2017.

A citizen's legal duty of care for biosecurity (a landholder's "biosecurity obligation") is proposed as an efficient legal principle.¹² Three States have legislated this approach.¹³ However we do not know how the landholders' duty rhetoric will deal with practical questions such as who will pay if private funds are insufficient (for example, during periods of extended drought or market downturns, or for disadvantaged groups such as Aboriginal landholders), how control programs will be coordinated, or how the obligation will be enforced over unwilling citizens.¹⁴ For these reforms to facilitate enforcement, or avoid the need for enforcement, is likely to require sophisticated legal and implementation approaches.¹⁵ Voluntary citizen engagement will remain a core requirement.

The many "we" s

A weed species lifecycle involves obtaining (possibly importing) genetic material, its introduction into the environment, distribution of the species, detection of harm, individual or collective action (or inaction) and the indirect actions that include obtaining permits and training, and even lobbying for or against control programs or methods.¹⁶ There are different people, industries, motivations and behaviours involved. Implementing a successful strategy may require various behaviour-management activities: public communications and advertising, landholder and citizen education, political action, and research and co-ordination of programs involving individual or group actions. Each is specialised, many are complicated, and success is not guaranteed.

The frontline "we"

At the frontline are landholders, government staff, and volunteers. Though it is easy to conceptualise these as homogenous categories, and to see 'motivation' as the central issue, this is simply incorrect. Each of these groups contains many behavioural segments with different worldviews, including views about invasive species. Our experimental work (as yet unpublished) has shown for example that for some landholders increasing public support for managing weeds on public lands is likely to motivate them to engage in voluntary work, but for almost as many the result will be for them to disengage from this work. Each of these groups contains a great variation in the capacity to engage and to do so effectively. It should not be surprising that weed control efforts in rural areas are affected by income fluctuation with markets, nor that farmers struggling economically often struggle with land management as well. Similar patterns exist for NGOs (observable with landcare engagement) and other volunteer organisations, and with government agencies.

¹² See Queensland Department of Agriculture, Forestry and Fisheries, *General Biosecurity Obligation* (2016)

¹³ Catchment and Land Protection Act 1994 (Vic) s 20; Biosecurity Act 2014 (Qld) s 23; Biosecurity Act 2015 (NSW) s 22.

¹⁴ Craik, Palmer and Sheldrake, n 11.

¹⁵ There is evidence of likely difficulties in applying a duty of care formulation of landholder obligations: Mark Shepherd and Paul Martin, "Using the Moot Court to Trial Legislation about Land Stewardship" (2011) 28(2) *Land Use Policy* 37.

¹⁶ The impediments to effective citizen actions in the control end of this pathway, identified by stakeholders in this system, are detailed in Martin et al, n 22.

Just behind the frontline are some industry organisations. Many of us would argue that they could do a lot more on invasive species issues. This is becoming a more pressing issue as government funding for the control of established species continues to shrink.

The big gap however, the most strategically pressing engagement issue, is the broader community. This has a number of dimensions, particularly economic and political.

The economic “we”

If the petrol tank is empty, the car is going nowhere, no matter how passionately those inside want it to or how important the destination. It is the same with natural resource policy: policies will fail unless all those who must take action have the resources required to carry out that action. This is true of landholders, government agencies, community groups and any other stakeholders.

Australia’s aspirations to manage invasive species harms through a community engagement approach are predicated on the assumption that if we can achieve sufficient motivation, we can achieve sufficient effective effort to control the problem. But is this assumption correct? Australia’s land is managed roughly 60% for agriculture and roughly 30% is under some form of indigenous control. There is an overlap between these categories. So, implicit in the expectation of effectiveness of shared responsibility is the assumption that farmers and aboriginal people have sufficient resources to do what is needed.

Resource constraints limit effective biodiversity protection.¹⁷ Some years ago we did a study for the Victorian government that indicated Australia needs around 2% of GDP for environmental investment to have a reasonable hope of managing the terrestrial environment sustainably. The NFF analysis of the GDP contribution of farming estimated that gross farming income was 2% of GDP. Given low farm profitability the amount of investable cash from farming would be a very small GDP percentage. This ‘back of the envelope’ analysis indicates that even assuming a strong commitment of farmers to sustainability, their funds would go only a little way towards what is needed. The capacity of Aboriginal landholders to invest in sustainability would be miniscule. As governments are generally attempting to reduce their frontline investment in managing established invasive species, it is likely that the funding gap will increase rather than diminish over time (unless rural incomes grow significantly on a sustained basis, or other significant investment sources are tapped).

Though insufficient funds are a major problem, gaps in knowledge, skills and data are no less important. These require experience and conscious learning (and thus can be particularly difficult and slow) to fill.¹⁸ People involved in invasive species management are generally aware of the need for better control methods to landholders and other

¹⁷ Paul Martin, “Ecological Restoration of Rural Landscapes: Stewardship, Governance, and Fairness” (2016) 24(5) *Restoration Ecology* 680.

¹⁸ Represented in the learning curve effect and the technology S-curve, which illustrate efficiency improvements from formal and informal learning over time and with experience.

frontline workers. Substantial effort is invested in invasive species extension activities. They are far less aware of the far larger capacity gap that limits the effectiveness of extension and other human interventions.

Extension activities are typically not well-informed by best practice knowledge ('human science' knowledge and expertise). There are many innovative approaches that are trialled, and there are some initiatives that seem, often on limited information, to work. But we lack empirical evidence of what works and what does not, and we lack the type of science-based continuing improvement that is generally seen as good practice in most human activities. This would tend to the conclusion that a lot of the scarce investment funds are not being optimally used to achieve behavioural goals. This is not intended as a criticism of the many excellent and committed practitioners who carry out this work – it is a system failing, not an individual failing.

The political “we”

I have participated in enough conferences and meetings with people who work at the frontline of invasive species management to know that most are well informed about the institutional challenges to effective weed control: social issues like irresponsible or absentee landholders; the frustrations and transaction costs of public funding and invasive species programs; unreliable regulation and enforcement; the bureaucracy and negotiation that consume limited resources. It is clear (and I think clear to everyone) that these institutional challenges must be overcome to change a long-established trajectory of increasing harm from invasive plants and animals.

But experience has led me to believe that people suffer from 'learned helplessness', complaining about issues but failing to engage to force essential change. Unless farming and environmental stakeholders create a strong imperative for reform, the institutional barriers will remain and probably increase, the frustrations will remain, and the outcomes will follow the trajectory once again highlighted in the most recent Australian State of Environment Report.

Australia's biodiversity is under increased threat and has, overall, continued to decline and most jurisdictions consider the status of threatened species to be poor and the trend to be declining. Invasive species, particularly feral animals, are unequivocally increasing the pressure they exert on Australia's biodiversity, and habitat fragmentation and degradation continue in many areas. The impacts of climate change are increasing.¹⁹

Our studies have led to specific proposals to address these issues. I am not so arrogant as to believe that these are the only solutions that are possible, or even that they are necessarily the best. I expect that an energetic effort to find solutions to the institutional problems that impede effective engagement would throw up others, and suggest refinements that would make our proposals more effective or perhaps redundant. Regardless of what solutions are

¹⁹ Ian Cresswell and Helen Murphy, "Biodiversity" in Department of the Environment and Energy, *Australia State of the Environment 2016* (2016) v <<https://soe.environment.gov.au/theme/biodiversity>>.

proposed, I agree with the proposition that it is insane to expect different results when we keep doing the same thing over and over again.²⁰ Better outcomes from weed management requires far more than the individuals concerned working harder and harder. Systems change is essential to achieve the type of engagement and the effectiveness from that engagement that will make a real difference.

We have proposed that meeting the national management challenges of invasive species will require an approach that is equivalent to that of water management and propose a COAG equivalent to the National Water Initiative, a National Invasive Species Initiative.

Australian governments need to address the risks that shared responsibility approaches may fail or may cause unanticipated negative impacts²¹.

1. Political risks, particularly preventing the implementation of necessary controls in a coordinated manner. We need to pursue a genuine consensus about what shared responsibility actually means so that it can be implemented efficiently.
2. We need to institutionalise more scientifically sophisticated methods for managing the human behaviour issues
3. A national investment strategy is necessary to address the economic risks. This would need to use a variety of instruments and structures, to make rural sustainability investments feasible.
4. High transaction costs and complexity of public programs create a risk of disengagement. Redesign with an emphasis on citizen-friendliness is needed to reduce these risks.

As government will continue to be hampered, other accountability mechanisms will be needed, including increasing citizen rights to oblige public agencies and private enterprises to act responsibly. New market instruments have the potential to make a substantial difference, for example incorporating invasive species status reports into property searches, or using private law and co-regulation to ‘strengthen the arm’ of the private nurseries and other plant distributors who are acting responsibly.

It is possible for Australia to close the gap between what we promise internationally and what we achieve locally. We have shown this capacity with the National Water Initiative (for all of the implementation difficulties) and in other fields, such as the dismantling of tariffs. It is daunting, but not impossible. However, progress will not occur unless we recognize that what we are doing now is not working, and never will, unless we lower the institutional barriers to putting the “we” into weeds management.

²⁰ A proposal popularly attributed to Albert Einstein but probably more correctly to John Dryden in his play *Spanish Friar* (act II, st. 1), 1681

²¹

Some relevant reports

1. P. Martin, "What Will It Take to Future-Proof Shared responsibility," in *Australian Vertebrate Pest Conference*, 2017.
2. P. Martin and K. Lingard, "Stakeholder Views on Pest Management in Australia," Canberra ACT, 2017 Invasive Animals CRC.
3. P. Martin and D. L. Choy, "Recommendations for the reform of invasive species management institutions," Invasive Animals Cooperative Research Centre, Canberra ACT, 2016.
4. P. Martin, D. L. Choy, E. LeGal, and K. Lingard, "Effective citizen action on invasive species: The institutional challenge," Invasive Animals Cooperative Research Centre, Canberra ACT, 2016.
5. P. Martin, "Cross pollination or cross-contamination? Directions for informing the management of invasives with market-economy concepts," in *16th Australian Weeds Conference*, 2008, pp. 6–13.
6. P. Martin, M. Verbeek, S. Riley, R. Bartel, and E. LeGal, "Innovations in Institutions to Improve Weed Funding, Strategy and Outcomes," RIRDC Canberra, ACT, 2012.
7. P. Martin, "Weeds: new strategies for an old problem," in *Managing Weeds in a Changing Climate*, 2005, pp. 118–121.
8. P. Martin, "Weeds: new strategies for an old problem," in *Fifteenth Australian Weeds Conference*, 2004, pp. 118–121.

CHAIN, CHAIN, CHANGE – PART ONE

Applying a behaviour change framework to tropical soda apple control in NSW - insights from the North Coast.

Elissa van Oosterhout¹, Reece Luxton², Wendy Gibney³ and Birgitte Verbeek⁴

¹ Development Officer - Weeds Information, New South Wales Department of Primary Industries, PMB 2 Grafton NSW 2460, Australia

Email: elissa.van.oosterhout@dpi.nsw.gov.au

² Senior NRM Officer (Vegetation Management), Clarence Valley Council, Locked Bag 23, Grafton, NSW 2460, Australia

Email: reece.luxton@clarence.nsw.gov.au

³ Development Officer - Community Weed Management, New South Wales Department of Primary Industries, 1243 Bruxner Highway, NSW 2477, Australia

Email: wendy.gibney@dpi.nsw.gov.au

⁴ Leader Invasive Species Extension, New South Wales Department of Primary Industries, Tamworth Agricultural Institute, 4 Marsden Park Road, Calala NSW 2340, Australia

Email: birgitte.verbeek@dpi.nsw.gov.au

SUMMARY This paper presents results from the application of community-based social marketing (CBSM) to a priority weeds issue in New South Wales (NSW). Behaviour change was sought to increase the control of tropical soda apple (TSA) (*Solanum viarum*) by landholders in the Clarence Valley on the North Coast. This was achieved by identifying high priority control activities (behaviours), researching barriers and benefits and then developing a behaviour change strategy. Evaluations made pre- and post-implementation show the approach has substantially increased landholder control of TSA.

Keywords: community-based social marketing, CBSM, weeds

INTRODUCTION

Since its identification in NSW in 2010, government authorities had been working with landholders to control TSA infestations on private land in an effort to eradicate it – a then State Prohibited Plant (under the *Noxious Weeds Act 1993*), and now regulated by Biosecurity Control Order (under the *Biosecurity Act 2015*). Good progress was made, and an opportunity to move closer to eradication by increasing levels of control undertaken by landholders themselves was realised. The CBSM framework was applied to the task of increasing control efforts by landholders and this paper presents the findings from each step: selecting behaviours (step 1), revealing barriers and benefits (step 2), developing a strategy (step 3), piloting the strategy (step 4), and implementing and evaluating the strategy (step 5). The collaborative project ran from December 2015 to June 2017 supported by NSW DPI and the Clarence Valley Council, funded by the NSW Weeds Action Program. In 2015 in the Clarence Valley, approximately 108 landholders were still dealing with infestations (a reduction of approx. 200 from initial infestations in the area) (Luxton, Ensbey & van Oosterhout 2016). The primary target audience for this project

comprised of 48 landholders with the lowest levels of control in the Tallawudjah Creek area, but all landholders with TSA were exposed to the strategy during implementation.

METHODOLOGY

CBSM is a five-step behaviour change framework applied globally to foster environmentally sustainable behaviour (McKenzie-Mohr 2011). A number of NSW DPI staff and regional weeds professionals have trained in CBSM with founder Dr Doug McKenzie-Mohr (Driver, Verbeek, van Oosterhout & Maguire 2015; Verbeek, van Oosterhout & Grantley 2014). The framework encourages use of proven social marketing techniques such as commitments, goal setting, norming, incentives, social diffusion, prompts, communication, framing and convenience. Strategies are developed only after very specific behaviours have been identified and the barriers to and benefits of those behaviours are known (researched with the target audience), rather than assumed.

STEP 1 – SELECTING BEHAVIOURS

Step 1 aimed to select 5-6 high priority behaviours that if increased, would have the greatest impact on the presence of tropical soda apple. An initial list was compiled through white-boarding sessions with the weeds officers. This was then assessed and prioritised (see Table 1) in terms of: each behaviour's impact (how much it would reduce the presence of TSA) and applicability to the target audience using an email survey of weeds professionals in the region (n=15); and each behaviour's probability (the likelihood of it being done) and penetration (the degree to which landholders are already doing it) through 30 minute telephone surveys with landholders (n=26).

Table 1. Results of the behaviour prioritisation process, in ranked order.

	Impact (score 1-5)	Probability (score 1-4)	Inverse Penetration (%)	Applicability (5)	Total score	Rank
Cut-stump	4.31	2.25	0.81	76	596.9	1
Hold cattle	4.69	2.64	0.77	62	591.1	2
Restrict grazing	4.46	2.35	0.87	60	547.1	3
Spray	4.54	2.16	0.41	88	353.9	4
Remove fruit	4.23	1.36	0.53	79	240.9	5
Dig or pull	3.69	3.17	0.12	81	113.7	6

Insights gained from the surveys and the need for chains of behaviours to achieve the end-state of control (i.e. spray, remove fruit, dispose of fruit) resulted in the following desired behaviours: Control plants (spray, cut-stump or dig/pull); Remove and dispose of fruit; Dispose of plant material; Hold cattle for 6 days; Restrict grazing from infested areas; Check control sites for regrowth; Check remainder of property for new plants.

STEP 2 – IDENTIFYING BARRIERS AND BENEFITS

Phone surveys were conducted with landholders (n=28) to identify the barriers and benefits of doing these activities. Open-ended questions about barriers and benefits were asked for each behaviour: *what would be difficult or challenging about doing x?*, and *what would be beneficial or worthwhile about doing x?* Table 2 presents the most frequent responses.

Table 2. Two most-frequently occurring barriers and benefits for each behaviour

Behaviour	Barrier responses (f)	Benefit responses (f)
Spray with herbicide	Prefer other methods (28) Not effective (13)	Best method (17) Effective (10)
Cut-stump	Prefer other methods (24) Would if advised (9)	Effective (13) See no barriers (9)
Dig/pull	Difficulty (21) Not effective (14)	Best method (23) Effective (19)
Remove fruit	Thorns (11) Time (9)	Stops spread (23) See no barriers (7)
Dispose of plant material	Thorns (5) Not convinced of need (5)	Stops spread (11) See no barriers (7)
Hold cattle	Not convinced of need (34) Costs (16)	See no barriers (26) Stops spread (19)
Restrict grazing	Not convinced of need (34) Not set-up (15)	Stops spread (16) See no barriers (16)
Behaviour	Barrier responses (f)	Benefit responses (f)
Check control sites	Time (16) Access/terrain (9)	Stops spread (15) Effective (14)
Check rest of property	Time (11) Finding plants (5)	Stops spread (13) Maintains control (12)

The most frequently described barriers were *prefer other methods* and *not convinced of the need*, and the most frequent benefits were *stops spread/regrowth* and *see no barriers*.

STEP 3 – STRATEGY DEVELOPMENT

Armed with a workbook detailing the known barriers and benefits for each behaviour, a group of regional industry representatives spent a day workshopping strategy ideas to minimise the barriers and maximise the benefits. The output was distilled further and aligned with proven social marketing techniques, resulting in a three-element strategy to be delivered by the weeds officers:

Coaching and call-backs (incorporating goal setting, prompts and feedback)

Beginning with a face-to-face property inspection with the landholder, the weeds officer used a helpful, supporting and serious approach (not threatening or coercive) to get the landholder to plan acceptable times and dates for each required behaviour. Arrangements were made for the weeds officer to call the landholder back (the day after completion if possible) to see how it went and plan the next step. Activity scheduling and call-backs

continued depending on what behaviours were still required, occurring alongside the council's usual quarterly inspection process.

Control cards (incorporating communicating, framing and convenience)

Double-sided control cards were developed for each behaviour, as well as a *worst case scenario/you can get on top of it* card addressing the barrier of *not convinced of the need*, and a card addressing the threat of fines and how to avoid being fined. A set of 8 laminated control cards on a flipper ring were taken to the inspection to help discuss the issues and the available options, and left with the landholder for reference. The cards were text-minimal, used motivational messaging techniques, and their content directly addressed the main barriers and benefits associated with the behaviour. An extensive literature review completed as part of step 1 assisted with technical content (Gibney in press).

Signs and maps (incorporating goal-setting, norming and diffusion)

During the property inspection, weeds officers asked landholders to display a 900 mm x 600 mm corflute sign on their property in a traffic light colour that denoted their progress. Green signs stated *Tropical soda apple CONTROLLED on this property*; orange stated *Tropical soda apple CONTROL IN PROGRESS on this property*; and red signs stating *Tropical soda apple UNCONTROLLED in this area* could be erected by the weeds officers in the road verge near properties making no control effort. 74% of landholders displayed signs, and only one red sign was erected. Maps (A2, laminated) showing infestations as coloured dots corresponding to the signs were created at a scale that identified the locality but not individual property boundaries. Maps were placed at local meeting places (shops, pubs, etc.) and A4 copies were taken to property inspections to show landholders.

STEP 4 – PILOTING THE STRATEGY

The strategy was piloted over two months in two other parts of the Clarence Valley where landholders were dealing with TSA – Coldstream/Pillar Valley (n=14) and Whiteman's Creek (n=17). Increases in levels of the behaviours were observed during the pilot, and small modifications were made: red signs were to be kept out of sight during the property visit but were kept on hand to illustrate there was a worse situation than being offered an orange sign; maps were modified to include an image of TSA and contact details for members of the public to report sightings (one new infestation was reported); a Notice of Entry letter was sent scheduling the initial visit and requiring the landholder's presence; and criteria were developed to define acceptable levels of activity, lengths of time for completion, colour of sign offered, and how hard to push the cattle-related activities.

STEP 5 – IMPLEMENTATION AND EVALUATION

The strategy was implemented in spring 2016, and levels of behaviours re-assessed in May/June 2017. Instances of landholders doing as advised doubled after implementation, and instances of landholders doing nothing decreased by two thirds (see Figure 1):

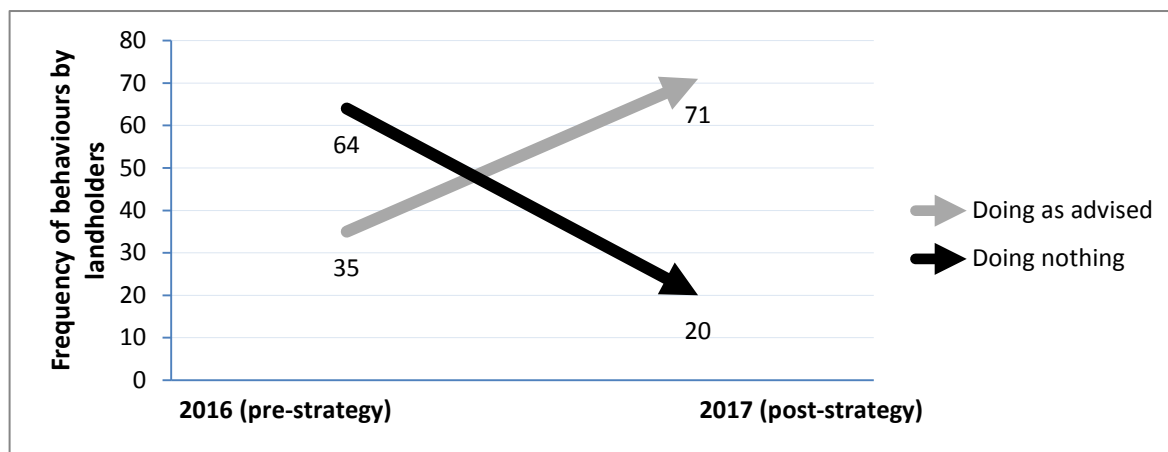


Figure 1. Landholder control of tropical soda apple in the Tallawudjah Creek valley, NSW, pre- and post-implementation of a community-based social marketing strategy.

DISCUSSION

The CBSM strategy has been successful in achieving positive behaviour change, and provides a solid benchmark for the application of CBSM to other weeds issues. The strategy will continue to be implemented and is currently being adapted for use in two other areas with TSA (New England Weeds Authority and Kempsey Council). CBSM has been criticised for the time it takes to apply, and while the lack of agreed best practice for such a new weed incursion and the issues around behaviour chains added complexity, our increasing experience with applying the framework will streamline future applications.

REFERENCES

- Driver A, Verbeek B, van Oosterhout E and Maguire A (2015), 'Two steps back five steps forward: Improving community participation in weed management' in *Proceedings of the 18th NSW Weeds Conference*, Cooma.
- Gibney W (in press) Tropical soda apple: literature review, NSW Department of Primary Industries, Wollongbar.
- Luxton R, Ensbey R and van Oosterhout E (2016) Control of tropical soda apple: five years on, in *Proceedings of the Twentieth Australasian Weeds Conference*, Perth.
- McKenzie-Mohr D (2011) *Fostering sustainable behaviour – An introduction to Community-Based Social Marketing*, 3rd Ed, New Society Publishers, Gabriola Island.
- Verbeek B, van Oosterhout E and Grantley J (2014) Social science methods to improve community participation in weed management programs in New South Wales, *Proceedings of the 19th Australasian Weeds Conference*, Hobart.

CHAIN, CHAIN, CHANGE – PART TWO

Applying a behaviour change framework to lantana control in NSW - insights from the Far South Coast.

Paul Martin¹, Elissa van Oosterhout² and Birgitte Verbeek³

¹ Invasive Species Supervisor, Eurobodalla Shire, PO Box 99, Moruya, NSW 2537,
Email: paul.martin@esc.nsw.gov.au

² Development Officer - Weeds Information, New South Wales Department of Primary Industries, PMB 2 Grafton NSW 2460, Australia
Email: elissa.van.oosterhout@dpi.nsw.gov.au

³ Leader Invasive Species Extension, New South Wales Department of Primary Industries, Tamworth Agricultural Institute, 4 Marsden Park Road, Calala NSW 2340, Australia
Email: birgitte.verbeek@dpi.nsw.gov.au

SUMMARY This paper presents results from the application of community-based social marketing (CBSM) to a high priority weeds issue in New South Wales. Behaviour change was necessary to increase and improve control and management of lantana (*Lantana camara*) by landholders in the Eurobodalla Shire on the Far South Coast. The project sought to increase specific control behaviours undertaken by landholders dealing with infestations, and after pilot testing over 12 months evaluation data indicates the approach has been successful. Full implementation will be carried out over the coming year.

Keywords: community-based social marketing, CBSM, splatter-gun

INTRODUCTION

This paper addresses the first four steps of the CBSM framework presenting the findings from each step: selecting behaviours (step 1), revealing barriers and benefits (step 2), developing a strategy (step 3) and piloting the strategy (step 4). The project is currently at implementation and evaluation stage (step 5), and has been running since July 2016. It is a collaborative effort between the Eurobodalla Shire Council and the South East Local Lands Service (SELLS) with assistance and guidance from NSW DPI. The project is a component of Council's Lantana Push Back program, which was funded by the Federal Government's Biodiversity Fund, and managed by the SELLS.

Lantana presents a serious threat to the biodiversity of the southern part of the Eurobodalla Shire Council area, having recently expanded its range between Narooma and Wallaga Lake, invading riparian zones and other high value forest environments. During the project it was declared under the *Noxious Weeds Act 1993* as a Class 3 Regionally Controlled Weed to be continually suppressed and destroyed. Community-based social marketing was sought as a way to increase and improve control behaviours, by breaking down barriers that prevent landholders from undertaking more long term, successful control. It was hoped that eventually this approach would reduce the level of Council resources needed to maintain control of lantana on private properties.

METHODOLOGY

Community-based social marketing is a five-step behaviour change framework applied globally to foster environmentally sustainable behaviour (McKenzie-Mohr 2011). A number of NSW DPI staff and regional weeds professionals have trained in CBSM with founder Dr Doug McKenzie-Mohr (Driver, Verbeek, van Oosterhout & Maguire 2015; Verbeek, van Oosterhout & Grantley 2014). The framework encourages use of proven social marketing techniques such as commitments, goal setting, norming, incentives, social diffusion, prompts, communication, framing and convenience to achieve behaviour change. Strategies are developed and piloted, but only after very specific desirable behaviours have been identified, and the barriers to, and benefits of, those behaviours according to the target audience are known (researched), rather than assumed.

STEP 1 – SELECTING BEHAVIOURS

Step 1 aimed to select behaviours that if increased, would have the greatest impact on the presence of lantana. Surveys of landholders and weeds officers were carried out using an Excel file to capture and analyse the data. Landholders were surveyed by phone (n=15) to understand the probability and penetration of a number of behaviours, taking between 15 minutes and 1.5 hours to complete each survey. Weeds officers (n=12) were surveyed about the impact of the behaviours, initially via email using the NSW DPI's online Weeds Behavior Selection tool (<http://weeds.contentlogic.com.au/>), which was also used to determine which behaviours would be surveyed, and then also by telephone. Surveys contained scaled, yes/no, and open-ended questions, capturing quantifiable data for probability, penetration and impact, as well as qualitative data for greater depth of insight. The data were analysed using Excel tools such as pivot tables, and the results are shown in Table 1. Difficulties conducting the research included defining a survey area that had not been exposed to other programs, obtaining an adequate sample size, and handling personal relationships between the weeds officer (interviewer) and the landholders that could bias responses (positively).

Table 1. Results of the behaviour prioritisation process, in ranked order

Behaviour	Impact (rating)	Probability (rating)	Current penetration	Inverse Penetration (from %)	Total Score	Rank
Splatter-gun	3.17	2.13	33.33%	0.67	4.52	1
Spraying	3.25	3.27	73.33%	0.27	2.87	2
Cut stump	3.08	1.33	33.33%	0.67	2.74	3
Mark on a map	3	0.9	6.7%	0.93	2.51	4
Monitor regrowth	3.42	3.8	93.33%	0.07	0.909	5
Check the property	3.25	3.8	93%	0.07	0.86	6
Re-treat	3.67	4.27	100%	0	0	7

STEP 2 – IDENTIFYING BARRIERS AND BENEFITS

Phone surveys were conducted with landholders (n=14) to identify the barriers and benefits of doing these activities. Open-ended questions about barriers and benefits were asked for each behaviour, and the results were as follows:

Table 2. Frequency of the barriers associated with the behaviours

	Check property	Mark on a map	Cut stump	Spot spray	Splatter gun	Re-treatment	Totals
Access	7	4	4	7	5	6	33
Difficult terrain	5	2	2	4	3	3	19
Time poor	3	2	4		5	3	17
None	4				2	3	9
Hard work			7				7
No point		5					5
Ticks/snakes	1		3				4
Infestation size	3						3
Environmental concerns				2			2
Other things to do		3					3
Inadequate access to equipment	2		2		1		5
	Check property	Mark on a map	Cut stump	Spot spray	Splatter gun	Re-treatment	Totals
Age/health	2		2				4
Cost					2		2
Lack of knowledge					1		1

Table 3. Frequency of the benefits associated with the behaviours

	Check property	Mark on a map	Cut stump	Spot spray	Splatter gun	Re-treatment	Totals
Easy/quick				5	9	9	23
Kills it			5	6	2	6	19
Property management	10	3					13
Don't go backwards	6						6
Incentive/funding	2	1				1	4
None			3	1			4
Aesthetics			1			3	4
Maximising coverage				4			4
Saves chemical			2		1		3
Satisfaction	1		2				3
Good for difficult terrain/access					3		3
Health benefits			1		1		2
Reduces follow up				2			2
Portable					2		2

Collectively across all behaviours, the most frequently described barriers were *Access*, *Difficult Terrain* and *Time Poor*, and the most frequently described benefits were *Easy / Quick*, *Kills it* and *Property management*.

Further insights to the behaviours (gained from the surveys) combined with the results of step 1 resulted in the decision to concentrate on a single desirable behaviour: **spraying lantana with a manual or gas-powered splatter-gun.**

STEP 3 – STRATEGY DEVELOPMENT

A strategy to minimise the barriers and maximise the benefits of landholders adopting the use of splatter-guns for control was developed from a workshop session between Council’s Invasive Species staff, resulting in the following five-element strategy:

Reducing availability and cost barriers: 18 gas-powered splatter-guns and associated equipment were purchased, located at the Council’s Narooma Depot, and maintained by Council. Landholders could book the equipment by contacting Council, and were given one full gas-bottle and sufficient Roundup Biactive herbicide to facilitate their initial knockdown effort.

Reducing lantana access barriers: Where necessary, the weeds officer developed a control plan with landholders, and engaged a contractor to clear access tracks to facilitate the initial knockdown.

Removing training and information barriers: The weeds officer conducted one-on-one training with each landholder, and made a follow up visit after one month to prompt and check control efforts. “How to” instructional cards were fixed to each splatter-gun.

Social diffusion, prompts and communication: landholders were supplied with a traffic-light-coloured gate sign stating the progress of their control (green = controlled; orange = control in progress; red = not controlled). Council ensured more properties displayed green than amber or red signs (to create a social norm). Landholders endorsed the sign as a public and personal commitment with their signature. Sign colour was changed as progress was made e.g. orange to green. Landholders were sent SMS, email or phone messages (as prompts) advising them to splatter-gun their lantana whenever conditions were good.

Monitoring: baseline spatial data of infestations and photopoints were captured. Equipment bookings were monitored and overlaid on GIS. Properties were revisited to determine how much, where and how work had been conducted. Spatial data was analysed for changes to infestation levels.

STEP 4 – PILOTING THE STRATEGY

The strategy was piloted in the Central Tilba area between July 2016 and July 2017, where 27 landholders were dealing with various infestation levels of lantana. A control group was also located in the Central Tilba area. Table 4 describes the treatment variables.

Table 4. Preliminary activities in pilot and control groups

Activity	Pilot group	Control group
Landholders were sent standard Noxious Weeds Inspection Letters under section 45 of the <i>Noxious Weeds Act 1993</i>	yes	yes
Infestations were mapped either by GPS on the property, or with severe infestations, desktop mapped	yes	yes
Landholders were sent a Property Inspection Report (PIR): an agreement inviting them to use the splatter-guns, undertake training, and if necessary, have access tracks cut	yes	no
Landholders were sent a PIR detailing their control requirements under the Act and a re-inspection date	yes	yes
Reinspection of properties to assess infestation levels and control efforts	yes	yes

Levels of behaviours were re-assessed in July 2017 with a sample of 15 respondents, with the main results indicating that the pilot strategy **increased levels of lantana control by 53%** and **reduced the presence of lantana from 68.95 ha to 24.45 ha** (Table 6). Other results are shown in Table 5:

Table 5. Landholder responses towards elements of the strategy (% of sample group)

Landholder responses	%
Availability of splatter-guns increased my control	66
My control would not have occurred if splatter-gun was not available	47
My control would still occur without supplied splatter-gun	13
I agreed to display a sign	53
Displaying a sign shows my commitment to others	70
Displaying a sign is positive/good	13
Displaying a sign is ugly/nobody would see it	28
I declined to display a sign – I don't want people to know	14

Table 6. Size of lantana infestation pre- and post-implementation of a CBSM strategy.

	Infestation (ha) June 2016	Infestation (ha) July 2017	Reduction (ha)
Pilot group	68.95	24.45	44.5
Control group	3.35	3.35	0

DISCUSSION

The pilot strategy has been successful with good adoption levels leading to a measurable positive change, clearly highlighting a difference between the pilot group and the standard compliance approach in the control group. The CBSM strategy will now be rolled out across the rest of Council's lantana control area.

REFERENCES

Driver A, Verbeek B, van Oosterhout E and Maguire A (2015), 'Two steps back five steps forward: Improving community participation in weed management' in *Proceedings of the 18th NSW Weeds Conference*, Cooma.

McKenzie-Mohr D (2011) *Fostering sustainable behaviour – An introduction to Community-Based Social Marketing*, 3rd Ed, New Society Publishers, Gabriola Island.

Verbeek B, van Oosterhout E and Grantley J (2014) Social science methods to improve community participation in weed management programs in New South Wales, *Proceedings of the 19th Australasian Weeds Conference*, Hobart.

A COMMUNITY BASED SOCIAL MARKETING APPROACH TO SERRATED TUSSOCK MANAGEMENT

Lessons from the Snowy River Region

Simon Mulvaney

Honours student, Fenner School of Environment and Society, The Australian National University, Canberra, Australian Capital Territory 0200, Australia.
Simon.Mulvaney@anu.edu.au

SUMMARY The acts of controlling and managing noxious weeds are intractable and complex problems. This is because noxious weeds are highly invasive, and expensive and time consuming to control. Managing noxious weeds has been a contentious topic plagued by many challenges including; inconsistent legislation, which often isolates individuals, and unsatisfactory education programs that rely on information provision and dissemination alone. These education campaigns have not achieved the behaviour change needed, and the extent and cost of noxious weeds has not reduced. The New South Wales Department of Primary Industries (NSW DPI) is now endorsing Community Based Social Marketing (CBSM) as a new strategy to engage with the community on the issue of noxious weeds and to achieve behaviour change. CBSM is a methodology aimed at influencing participant's behaviour to improve sustainability outcomes and encourage actions that are collective and coordinated. This study was completed in the Snowy River region (SRR) of NSW, now part of the Snowy Monaro Regional Council (SMRC). The aim was to examine the current challenges of managing *Nassella trichotoma* (Nees) Hack. ex Arechav. (serrated tussock) in the SRR; and to analyse the extent to which the CBSM methodology can assist in better addressing and reducing the problem of managing serrated tussock in the region.

The findings were both compatible and highly relevant to the changes recommended through the *NSW Biosecurity Act 2015* and *South East Regional Strategic Weed Management Plan 2017-2022* around: a regional focus to weed prioritisation rather than 'blanket policy'; using information and mapping systems to improve control; better cross property communication and collaboration; integrated land and weed management as a way to contain weeds in widespread areas; and opening more formal and informal avenues for dialogue between weed experts and landholders, to agree on the most effective ways of proceeding with weed control.

Keywords: community engagement, collective action, participation

INTRODUCTION

Noxious weeds like serrated tussock have the potential to totally or permanently transform ecosystems, threaten livestock, crop growth and production, limit biodiversity and harm human health (Blackmore 2008, Csurhes and Edwards 1998). A failure to manage weeds has direct implications for both food security, through loss of agricultural productivity, and biodiversity. Serrated tussock has been a prevalent invasive species in the Australian

agricultural context since the early 1900's. Numerous attempts have been made in Australia to control or even eradicate serrated tussock with limited success (McLaren et al. 2005). There is now recognition in the literature that a more realistic goal for managing serrated tussock is annual control and suppression, rather than complete eradication (Pearson et al. 2016, Vere and Campbell 1984).

As a result, there is a mandate to explore whether a behaviour change approach, like CBSM will enable a more coordinated effort from stakeholders to target weeds strategically using a range of different techniques concurrently. The belief in the literature is that behaviour change approaches provide greater opportunity for cross property collaboration, increasing awareness around, and knowledge of weeds, and collective community action when targeting weeds (McKenzie-Mohr 2000).

The CBSM approach

Mackenzie-Mohr (2000), defines CBSM as an effective behaviour change tool to provide an alternative to information intensive campaigns. Education campaigns often rely solely on information brochures and advertising, while a CBSM approach seeks to understand the problem, identify the stakeholders and use a range of strategies to achieve education based change (McKenzie-Mohr 2011). CBSM strategies include: getting the community to pledge, and commit their support to the project; building community support through social norms; facilitating new behaviour through social diffusion; using visual and auditory prompts when speaking to the community; communicating key messages successfully using specially targeted advertising; offering incentives to enhance motivation to act; and making the strategy convenient for the community to implement (McKenzie-Mohr 2000). CBSM utilises a five step approach to mobilise action involving: (1) selecting a particular behaviour that most needs changing; (2) identifying the barriers and benefits of targeting that particular behaviour; (3) designing a strategy based on overcoming the barriers previously identified; (4) testing a pilot program in a small community; and (5) implementing the program more broadly if the pilot program is successful (McKenzie-Mohr 2000).

MATERIALS and METHODS

In line with the CBSM methodology, the data collected in this study were: participant observation in the SRR; quantitative surveys of 'weeds experts' and geographical cluster sampling of local landholders by phone interview; and purposive and snowball sampling of 'weed experts' and NVivo analysis. 'Weeds experts' participating in the research included staff from: the SMRC; Office of Environment and heritage (OEH); NSW DPI; CSIRO; The Australian National University; Local Land Services (LLS); and University of Sydney. In addition to these CBSM processes, statistical analysis for significant difference compared to data from the research groups of 'weeds experts' and local landholders.

Study site

This study was conducted across the SRR, an area categorised largely by cleared farmland, but also with 32 recorded unique vegetation communities, including vulnerable ecosystems.

The CBSM methodology

Stage one involved selecting several behaviours that most needed to be changed using an equation that takes into account the impact, probability and penetration. The data was collected using a sample size of 33 landholders from the region and 15 weeds experts. Impact was determined by a Likert scale rating of how effective ‘weeds experts’ and landholders believed each behaviour to be. Probability was determined by asking landholders whether they will conduct each behaviour in the future. Similarly penetration was determined by asking landholders whether they were currently using/ implementing each behaviour. From the outset, the study identified 47 different types of behaviours that could be targeted using CBSM with the aim of improving serrated tussock management. Behaviours were categorised into prevention measures, reduction measures, control of regrowth and germination measures and communication and reporting.

Stage two and three involved identifying barriers that would impede progress towards achieving implementation of the selected behaviours from stage one, and determining strategies to pursue. Qualitative interviews were conducted with 15 weeds experts who described the kinds of barriers faced for serrated tussock management, which were then categorised by theme using qualitative data analysis software *NVivo*. Stage four involved conducting a Mann-Whitney U test based on a chi-square statistic to test non-parametrically whether the tested landholder group and ‘weed experts’ group were different on the stage one behaviours.

RESULTS AND DISCUSSIONS

This study found that in the area of serrated tussock management, and other weeds more broadly, there is certainly scope to pursue the CBSM methodology further, provided the limitations of the approach are also acknowledged. Using the CBSM methodology, stage one of the process prioritised: the creation of integrated weed management plans (IWMPs) on individual properties; coordinated cross property control, including sharing equipment and treating serrated tussock collectively; introducing perennial pastures; and inviting vegetation management officers to visit properties directly. Stage two of the process identified seven separate barriers to serrated tussock control across three different categories. They were: biophysical and biochemical barriers such as the high initial invasiveness and potential for spread of serrated tussock; social barriers such as landholders lacking an apathy to learn, and an apathy to act on knowledge, a barrier that was noted 24 times by seven ‘weed experts’; and institutional barriers such as a lack of flexibility in legislated weed management requirements, legislation that applies to individuals rather than collectives, and no incentives for control, although these barriers are reducing under the implementation of the *NSW Biosecurity Act 2015*. Often the

assumption is that barriers for weed management are simply time and money, however, this was not the case in this study.

Based on the behaviours and barriers discovered in stages one and two, stage three identified three key strategies that should be pursued under a CBSM pilot program. These strategies were:

1. The proposal for an updated de-identified publically available distribution map of serrated tussock in the region. A map was last publically released in 2010, and a similar approach would be beneficial to map changes to this base line data in 2017 and gather more detailed information about the spread and decline of serrated tussock across NSW.
2. The need for collective actions and cross property communication between landholders.
3. The need for landholders to consider integrated approaches to controlling serrated tussock, including IWMPs which are known to create a suite of responses to serrated tussock.

Statistical analysis was also conducted on stage one of the CBSM methodology and found a significant disparity between expert and landholder opinion for 26 out of 49 behaviours surveyed. Resolving this disparity of opinion will require weed experts and landholders to come together to discuss existing strategies, particularly in the context of collective action and behaviour change.

To answer the research question of whether a CBSM approach to serrated tussock should be pursued further, it is necessary to evaluate the strengths and limitations of the approach. The strengths of the CBSM approach in terms of potential and ability to create behaviour change outweigh the limitations that exist with the approach. Limitations exist around the scope and scalability of CBSM. In this context, the dominant agricultural production paradigm is given priority over minority interests in weeds management. The difficulty is that landholders are a diverse group of individuals with different interests including managing weeds for reasons of biodiversity, lifestyle, and community, as well as for production (van der Meulen *et al.* 2006). Another limitation of the CBSM approach is around upscaling the research to a wider audience. There is a risk that the results gathered in this small research setting might not be relevant to the rest of NSW, so a highly iterative process is essential to ensure that upscaling can meet any unexpected policy outcomes. From here, while CBSM was found to be an effective strategy to understand and apply to serrated tussock management in the SRR, it must be pilot tested to see whether a behaviour change approach will result in tangible reductions in serrated tussock. If successfully piloted, the CBSM program should be expanded to assist with broader control measures for serrated tussock across NSW.

ACKNOWLEDGEMENTS

Thank you to my research supervisors, Dr John Field, Dr Viveka Turnbull Hocking, Dr Rob Dyball and Richard Hocking and to Jean-Monique Hawkins from the Snowy Monaro Regional Council.

REFERENCES

- Csurhes, S., and Edwards, R. (1998). 'National weeds program, potential environmental weeds in Australia', p208. (Environment Australia, Canberra).
- Blackmore, P. (2008). 'Noxious weeds or just obnoxious', p.3. (Primefacts, Orange).
- McKenzie-Mohr, D. (2000). Fostering sustainable behavior through community-based social marketing. *American psychologist* 55(5), 531.
- McKenzie-Mohr, D. (2011). Fostering sustainable behaviour: an introduction to community based social marketing. 3rd edition. (New Society Publishers, Gabriola Island).
- McLaren, D., Ramasamy, S., Lawrie, A., Pritchard, G. and Morfe, T. (2005.) The national serrated tussock survey—impacts and implications of its resistance to the herbicide, flupropanate in Australia, proceedings of the Tussock Terminators Research Forum.
- Pearson, D. E., Ortega, Y. K., Runyon, J. B. and Butler, J. L. (2016). Secondary invasion: The bane of weed management, *Biological Conservation* 197, 8-17.
- van der Meulen, A., Reeve, I., Sindel, B., Preston, C., Watts, J. and Crossman, N. (2006). Insights into motivations and barriers for weed control in grazing districts of southern Australia, *proceedings of the 15th Australian Weeds Conference*.
- Vere, D. and Campbell, M. (1984). Economics of controlling serrated tussock in the southeastern Australian rangelands, *Journal of Range Management Archives* 37(1), 87-93.

RETHINKING COMMUNITY ENGAGEMENT APPROACHES: SYSTEM-STRENGTHENING FOR INVASIVE SPECIES MANAGEMENT

Tanya M Howard, PhD.

Post-doctoral Research Fellow, Australian Centre for Agriculture and Law, University of
New England

email: thoward9@une.edu.au

SUMMARY People working with community members to achieve coordinated invasive species management are usually trained in aspects of weed ecology. They hold great expertise in control techniques and understand the biophysical, social and economic impacts of weeds on agricultural and biodiversity values. In NSW and other parts of Australia, the development of a ‘general biosecurity duty’ is increasing the focus on individual landholder responsibilities for widely established invasive species. Front-line weed control staff increasingly need to use their ‘people skills’ to deal with situations of community conflict, disengagement and frustration with weed control issues. Dealing with these different situations extends beyond invasive species expertise and requires an understanding of social dynamics.

Working with community to achieve collective action is best understood as a community development exercise. □Community development is associated with the use of participatory techniques for planning and evaluation, and may support the devolution of power from government to community members through a range of different mechanisms such as partnerships, collaborations or co-management arrangements. Each of these require different degrees of participation from the community, industry and government, in a dynamic model of learning and experimentation, if they are to realise their potential. □ This paper considers how participatory approach to systems mapping may support community engagement, with reference to a recent example in Victoria

KEYWORDS

Community engagement; natural resource management; social science; community development.

INTRODUCTION

Back in the 1969 Shelly Arnstein developed the famous ‘Ladder of Participation’ (Arnstein, 1969). You have probably seen it, and may have used the terminology to guide a community engagement process or activity. The reason this remains the foundational work for community engagement is that Arnstein was articulating something profound that is still powerful and relevant today. This is the simple fact that working with community is a political act. It has implications for allocation of resources; recognition of different viewpoints; inclusion or exclusion of dissenting voices. It can be used as a political strategy, manipulating community concerns and interests to achieve a desired outcome.

Since the Ladder was introduced to the world, there have been a plethora of ‘how to guides’ and ‘best practice’ instruction manuals that focus on the ways and means to work

with communities to get a desired outcome. These guides are useful but they rarely prompt us to think deeply about the political or philosophical foundations of our efforts to bring community members into a decision making process or a collective action endeavour. While we may be able to distinguish between ‘consult’ and ‘inform’, it is much more challenging to think about what ‘citizen power’ might actually look like – and what changes to the status quo might be necessary to really achieve it.

In this paper, I suggest that working with community to achieve collective action can be helpfully understood as a community development exercise. □For collective community action to be sustained over time, individual citizens must feel that they are in control of their action, or exercise some form of delegated power.

Community development is associated with the use of participatory techniques for planning and evaluation, and can support the devolution of power from government to community members through a range of different mechanisms such as partnerships, collaborations or co-management arrangements (Reed, 2008). Each of these requires different degrees of participation from the community, industry and government, in a dynamic model of learning and experimentation, if they are to realise their potential. Learning about community development requires reflection on success and failure, as well as an individual commitment to do things differently (Eversole, 2011)□.

This paper draws on a recent study of community action for *Nassella trichotoma* (serrated tussock), *Ulex europaeus* (gorse) and *Rubus anglocandicans* (blackberry) control in Victoria to illustrate how community centred research approaches may be used to strengthen community action for weed management.

METHODS

Working within a system-strengthening framework, the study used a range of qualitative research methods to investigate community action for widely established weeds and identify possible intervention points to strengthen this action.

- The study began with a literature review of key concepts then conducted semi-structured interviews (n=79) and focus groups with a range of participants in the weed management system.
- Questions were focused on understanding what influenced their decisions, where they looked for information and resources, and what gaps or tensions they saw in the management system.
- This data was then thematically analysed and the research team worked together to develop a visual depiction of the weed control system described by the data, resulting in a set of weed specific system maps.
- These maps were presented to a large workshop hosted by the commissioning agency, and the research team captured observations and responses from the day,

RESULTS

- 4 system maps – one for each weed and a generic ‘overview’ of the interaction between landholders, contractors, government and industry. Each map was accompanied by a description that unpacked the map, including the key information and resource flows, major disconnections or gaps, where assets were identified and any feedback loops that emerged.
- 3 weed specific narratives that told the story of each weed management system and aimed to incorporate the voices of the study participants. These narratives included key phrases and words from the interview transcripts. The narratives were made available to participants at the workshop and aimed to prompt the readers to react through agreement, disagreement or questions. This interaction might then deepen their understanding of the issue and encourage a dialogue to develop, rather than presenting an expert-driven, authoritative version of the issue.
- All of the data were incorporated into the report submitted to the project control board. This report combined with participatory decision-making mechanisms to establish the foundation for a suite of 6 strategic interventions designed by the Board members and currently being implemented in Victoria.

DISCUSSION

This study was underpinned by a philosophical commitment to community development and democratic co-creation of knowledge. In this paradigm, the starting point for community is the individual citizen, who holds diverse values and specialized knowledge informed by their personal experience of politics, power and place. The intersection of these diverse perspectives is seen as a necessary ingredient for effective and sustained collective action (Fischer 2005). Intersection creates opportunities for innovation, creativity and insight; however it also presents challenges for all stakeholders working to address complex problems such as invasive species control.

A good starting point for any work focused on community action is that:

- Invasive species management is a community problem that requires collective action – in order to achieve best results across the landscape;
- And that requires people to work together to develop a shared vision and shared commitment – because we need that action to be sustained over time in order to address the persistent nature of invasive species.

The problem we are observing is dynamic, evolving and unpredictable. Natural science examines the interaction of ecological and agricultural systems with species ecology. Social science helps us understand the other dimensions of this problem – the economic, political and psychological factors that shape human behavior. These can be categorised as social or structural dimensions of the issue.

Social dimensions include:

- Values, motivations, behaviors – how do people work together? Why DON'T they work together? What incentives or support do they need?

Structural dimensions include:

- Economic advantage/disadvantage, legal and political settings (institutional), policy directions, and the consequences, both intended and unintended, of invasive species control agendas.

Too often we gloss over the implications of these social, political and economic interactions in our efforts to get people implementing invasive species control.

To improve, we need to connect our ambitions for landscape management with broader ideas of community development.

If we accept that “*invasive life... has the power to create communities*” (Everts 2015), then as practitioners, policy makers and landholders we can strive to develop the shared recognition, understanding and acceptance of a threat that will support community building, and may then lead to a shared decision to act collectively.

The final take-home message is that successful community action shifts power dynamics - this is the uncomfortable truth of community engagement! Best to be prepared, embrace the potential and work towards the best possible outcome.

ACKNOWLEDGEMENTS

The author was part of the research team contracted by the Victorian Government to support the systems-strengthening approach to the management of established pest animals and weeds in Victoria. Lisa Adams and Associates convened the research team, and the author acknowledges the team members: Lisa Adams, Prof Ted Alter, Dr Brian Furze, Anthony Gallacher and Anna Semmens.

The author also acknowledges the Project Manager, members of the Delivery Leadership Group and Project Control Board for the project, and the 100 plus study participants and particularly the community volunteers for their willingness to share information and ideas from their involvement in the management of invasive plants and animals.

The author has been Post-doctoral research fellow (2015-2017) in the Invasive Animals CRC program “Facilitating Effective Community Action” and acknowledges the program leaders: Professor Paul Martin, University of New England; Professor Ted Alter, Pennsylvania State University; Professor Don Hine, University of New England; and Professor Daryl Low-Choy, Griffith University.

REFERENCES

Arnstein, S. R. (1969). A Ladder of Citizen Participation. *Journal of the American Institute of Planners*, 35(4), 216-224.

Bridger, J. C., P. Frumento, T. R. Alter and M. A. Brennan (2013). A framework for thinking and acting critically in community. In 'Theory, Practice and Community Development'. ed. M. A. Brennan, J. C. Bridger and T. R. Alter. (Routledge, Great Britain).

Eversole, R. (2011). Community Agency and Community Engagement: Re-theorising Participation in Governance. *Journal of Public Policy*, 31(1), 51-71.

Everts, J. (2015). Invasive Life, Communities of Practice , and Communities of Fate. *Geografiska Annaler: Series B, Human Geography* 97(2): 195-208.

Fischer, F. (2005). 'Citizens, Experts and the Environment: the Politics of Local Knowledge' (1st ed.). (Duke University Press, Durham, NC).

Reed, M. (2008). Stakeholder participation for environmental management: A literature review. *Biological Conservation*, 141(10), 2417-2431

AN INCONVENIENT TRUTH

Weeds in urban landscapes

Wendy Bushell

Catchment Weed Biosecurity Officer, MidCoast Council, Taree
Wendy.Bushell@midcoast.nsw.gov.au

SUMMARY Many of our weed problems spread from urban areas. Statistics gathered over a number of years support what we already know – that older parts of towns, and usually the original village, are likely to harbour the old, now weedy plants.

This paper illustrates the importance of recognising, acknowledging, and dealing with the sources of weeds and the process of addressing these issues at inspection. This proactive approach has been implemented on declared species, those already recognised as weedy, and future threats. During this process community awareness is raised using a personal approach rather than group forums.

Preparedness to take this proactive approach has huge potential to reconnect the urban population with the farming community by bringing urban landholders focus onto the negative impact gardening practices can have on agricultural and environmental landscapes. It also provides opportunities for urban landholders to connect with Landcare and often brings positive engagement with Local Control Authorities.

Keywords: urban, community, weeds, threats, gardening, awareness

PROCESS

Urban properties inspected town / village at a time. Same process followed as per normal inspection procedure, with focus specifically on declared species. Landholders formally notified of species that needed to be addressed, as necessary. Statistics correlated at end of process and infestation percentages comparisons made over time.

RESULTS

Comparison of urban statistics supports previous published data on urban landscapes are a primary source of weeds, of both established and emerging threats, in garden escapees.

Talking with urban landholders can reveal some interesting comments that illustrate the evolution of the disconnect between rural and urban activity and general lack of awareness regarding weeds in urban areas.

CONCLUSION

A proactive approach recognises huge potential to reconnect the urban population with the farming community by bringing urban landholders focus onto the negative impact gardening practices can have on agricultural and environmental landscapes. It also

provides opportunities for urban landholders to indirectly support local agricultural productivity, the environment, connection with Landcare, and often brings positive engagement with Local Control Authorities.

Further reading:

Plant introductions in Australia; how can we resolve 'weedy' conflicts of interest, John G. Virtue, Sarita J. Bennett and Roderick P. Randall Fourteenth Australian Weeds Conference

Weed Management 'A Paradigm Shift' Terry Schmitzer 2009 15th Biennial NSW Weeds Conference. Conference Proceedings.

Garden Escapees & Other Weeds of Bushland and Reserves, 3rd Edition. Mid Coast Weeds Co-ordinating Committee.

COMBATTING GLYPHOSATE RESISTANT WEEDS ALONG FENCE LINES AND ROADSIDES

Tony Cook, Technical Specialist Weeds, Tamworth, NSW DPI.

Bill Davidson, Technical Officer, Tamworth, NSW DPI.

Email: tony.cook@dpi.nsw.gov.au

INTRODUCTION A change of practice is required for roadside and fence line weed management. There is increasing evidence showing the demise of glyphosate-based treatments. A diversity of weed species are now on the glyphosate resistance register and are reported to be found along road sides and fence lines (Preston 2017). As a result, glyphosate resistant weeds such as flax-leaf fleabane, common sowthistle, windmill grass, annual ryegrass and feather-top Rhodes grass are thriving in these environments. Most of these species have wind-blown seeds and can rapidly infest other areas causing more problems.

The reduced efficacy of glyphosate has necessitated research into alternative chemical options. Despite the broad range of alternative herbicides, most of these are not suited because of their limited weed control spectrum, high potential for off-target impacts, or lack of registration for these situations.

In response to this need, NSW DPI has completed 12 experiments on the glyphosate resistant weed species previously mentioned. Although there is a need for further refinement of treatments in future years, the preliminary findings are worthy of highlight and discussion in this paper. Potentially, there are five alternative modes-of-action herbicides that have some potential for commercial control of these weeds.

The long term objective of this research is to obtain more registered effective treatments and thus achieve excellent control of glyphosate resistant weeds along fence lines and roadsides. With improved management of weeds in these areas, the level of quarantine is augmented and the spread of glyphosate resistance is minimised.

MATERIALS AND METHODS

All the experiments reported in this paper were located under field conditions in New South Wales (except one experiment in Queensland for feather-top Rhodes grass). Application of herbicides was via a hand-held boom-spray at spray water volumes of 100L ha⁻¹. Sites were generally located along fence lines or irrigation channels. No site was selected along a road side because of operator safety issues and possible compromising of results due to high frequency of public movement.

Application of adjuvants was in accordance to label directions for each specific product. All plants were treated when actively growing to ensure treatment effects were not impacted by moisture stress interactions. All but one experiment was applied to post-

emergent weeds: the feather-top Rhodes grass experiment was the only pre-emergence focused research.

Herbicide efficacy assessments comprised of either plant counts per treated area or rating of biomass necrosis using a scoring system with nil effect being a score of zero and full control a score of five. Alternatively a 0 to 100% biomass control rating was used. All experiments were concluded after regular inspections indicated there were signs that the best treatments had passed their peak control levels. This was to ensure results presented within this paper reflect longer term performance of treatments not short-term brown-out effects.

The following experiments and treatment details are listed in the following table:

Table 1. Experiments undertaken on various fence-line or roadside weeds.

Exp No	Spray date(s) d/m/y	Location	Weeds investigated	Herbicides used (herbicide group)	No. of treatments
EX P1	3.1.13	Bellata	Fleabane and common sowthistle	Glyphosate (M), bromacil and terbacil (C), sulfometuron (B) & clopyralid (I)	7
EX P2	8.12.12	Bellata	Fleabane and common sowthistle	Simazine (C), bromacil (C), sulfometuron (B) & imazapyr (B)	12
EX P3	6.8.14 & 28.8.14	Narromine	Fleabane, common sowthistle & windmill grass	Glyphosate (M), clethodim (A), bromacil and atrazine (C), imazapyr (B), paraquat (L) & amitrole (Q)	13
EX P4	8.8.14 & 26.8.14	Nyngan	Windmill grass	Bromacil (C), imazapyr (B), paraquat (L) & amitrole (Q)	15
EX P5	12.8.16	Coolah	Annual ryegrass and common sowthistle	Bromacil and diuron (C), imazapyr (B), glyphosate (M), sulfometuron (B) & amitrole (Q)	15
EX P6	8.9.16	Tamworth	Fleabane and common sowthistle	Bromacil and diuron (C), imazapyr (B), glyphosate (M), sulfometuron (B), saflufenacil (G), 2,4-D (I) & amitrole (Q)	15
EX P7	13.12.16	Trangie	Windmill grass and common sowthistle	Bromacil and diuron (C), imazapyr (B), glyphosate (M), sulfometuron (B) & amitrole (Q)	15

Exp No	Spray date(s) d/m/y	Location	Weeds investigated	Herbicides used (herbicide group)	No. of treatments
EX P8	31.11.16	Tara - QLD	Feather-top Rhodes grass (pre-emergence)	Bromacil and diuron (C), imazapyr (B), sulfometuron (B) & amitrole (Q)	15

RESULTS

EXP 1: Various combinations with bromacil to control flax-leaf fleabane and common sowthistle – Bellata, NSW.

The primary aim of this experiment was to test a range of herbicides to control established fleabane and determine the residual effect of these treatments of common sowthistle and fleabane.

Table 2. Herbicide efficacy assessments (plants per plot and biomass necrosis) on fleabane and common sowthistle using various residual herbicides, 61 days after treatment (DAT) and 7 months after treatment (MAT).

Treatment (rate per hectare)	Fleabane plants per plot (40m ²) 61 DAT	Fleabane control (0-5) 7 MAT	Sowthistle control (0-5) 7 MAT
Bromacil 3.5kg	0.0	5.0	5.0
Bromacil 3.5kg + sulfometuron 300g	0.0	5.0	5.0
Bromacil 3.5kg + sulfometuron 600g	0.0	5.0	5.0
glyphosate 700 1.6kg + Trimac [®] 1kg	9.7	0.3	0.3
glyphosate 700 1.6kg + Trimac [®] 1kg + clopyralid 400g	3.7	1.2	1.7
glyphosate 700 1.6kg + Trimac [®] 1kg + sulfometuron 560g	3.0	0.3	0.3
glyphosate 700 1.6kg + Trimac [®] 1kg + sulfometuron 260g	6.0	0.3	0.0
glyphosate 700 1.6kg + Trimac [®] 1kg + clopyralid 400g	3.7	1.2	1.7
untreated	25.7	0.0	0.0

NOTE: formulation concentrations were: bromacil 800 g kg⁻¹; sulfometuron 750 g kg⁻¹; Trimac[®] (terbacil 880 g kg⁻¹ + 40 g kg⁻¹ sulfometuron); clopyralid 750 g kg⁻¹. Control score 5 = total control.

Rainfall: Monthly rainfall totals were as follows; November 5 mm, December 125 mm, January 234 mm, February 73 mm, March 87 mm and April 0 mm. This equates to 524 mm or 21 inches of rain, an exceptionally large amount of rainfall that would increase the

likelihood of herbicide breakdown and leaching leading to poor persistence of the residual herbicides

Fleabane control: Bromacil was the herbicide of choice for the control of fleabane. All three treatments containing bromacil killed all established flowering/seeding plants and maintained excellent control up to 7 months after treatment.

There is a need to apply this herbicide at much lower rates to reduce the cost and impact on off-target species (shrub/trees) that maybe adjacent to farm tracks. Efficacy may be maintained at these lower rates (refer to EXP2 results).

Trimac (terbacil + sulfometuron) was another product that resulted in reasonable control of established fleabane especially if mixed with Clomac[®] (clopyralid) or Sulfomac[®] (sulfometuron). Having said this, residual control of these treatments was poor at the 7 month after treatment inspection.

Sowthistle control: The residual activity of at least bromacil at 3.5kg ha⁻¹ ensured 100% control of sowthistle up to seven months after treatment.

EXP 2: Rate response of four residual herbicides and their effects on flax-leaf fleabane and common sowthistle – Bellata, NSW.

The primary aim of this experiment was to determine rate responses for four registered herbicides of non-crop areas, particularly for longer term control.

Table 3. Control of fleabane and common sowthistle using increasing rates of four residual herbicides, 8 months after treatment (MAT)

Treatment (rate per hectare)	Rate of product per hectare	Fleabane control (0-5)	Sowthistle control (0-5)
sulfometuron	50g	0	0
sulfometuron	100g	0	0
sulfometuron	200g	0	0
bromacil	0.55kg	4.9	5.0
bromacil	1.1kg	5.0	5.0
bromacil	2.2kg	5.0	5.0
simazine	5L	0	1.0
simazine	10L	0	2.5
simazine	20L	0	2.0
Treatment (rate per hectare)	Rate of product per hectare	Fleabane control (0-5)	Sowthistle control (0-5)
imazapyr	1L	0	0
imazapyr	2L	2.5	1.0
imazapyr	4L	2.7	2.2

NOTE: formulation concentrations were: bromacil 800g kg⁻¹; sulfometuron 750g kg⁻¹; simazine 500g L⁻¹; imazapyr 250g L⁻¹. Control score 5 = total control.

Fleabane control: Bromacil was the herbicide of choice for the control of fleabane. All three treatments containing bromacil killed emerging seedlings for up to 8 months after

treatment. Furthermore, it is extremely active against fleabane because dose rates as low as 0.55 kg ha⁻¹ were highly effective. This rate represents a quarter of the lowest registered rate for other crops e.g. pineapples, half the lowest rate in asparagus crops and situations such as orchard groves. There is a possibility to applying this herbicide at lower rates to further reduce the cost and impact on off-target species (shrub/trees) that maybe adjacent to farm tracks.

Sowthistle control: Bromacil appears to be the superior choice for long term residual control of this weed. Again rates in this experiment could have been lowered to determine the sensitivity of sowthistle.

EXP 3: Controlling Group A (selective grass herbicides) and M (glyphosate) resistant annual ryegrass along crop margins and fence lines – Narrromine, NSW.

In this experiment the annual ryegrass was well advanced in growth stage, having at least 20 tillers and 20 to 30 cm tall. The inclusion of a 2nd knock of paraquat was applied to some treatments to increase the rate of weed brownout (early plant necrosis, particularly on foliage) 20 days later.

Table 4. Control of annual ryegrass (ARG), windmill grass and common sowthistle using post-emergence and residual herbicides.

Treatment (rate per hectare)	ARG seed heads per plot	Windmill grass plants per plot	Common sowthistle plants per plot
Untreated	1430	30	14
glyphosate 2L	1300	15	5
clethodim 500mL	7500	0	5
clethodim 500mL + 2 nd knock of paraquat + 2.4L	740	33	1
paraquat 2.4L	1300	32	3
paraquat 2.4L + 2 nd knock of paraquat + 2.4L	22	140	6
Alliance® 4L	220	68	7
amitrole 4L	520	22	11
bromacil 1kg + imazapyr 1L + 2 nd knock of paraquat 2.4L	170	0	2
bromacil 2kg + imazapyr 1L + 2 nd knock of paraquat 2.4L	13	0	0
bromacil 1kg + imazapyr 2L + 2 nd knock of paraquat 2.4L	1	10	0
bromacil 2kg + imazapyr 2L + 2 nd knock of paraquat 2.4L	0	0	0
atrazine 10L + paraquat 2.4L	0	0	0

NOTE: formulation concentrations were: bromacil 800 g kg⁻¹; sulfometuron 750 g kg⁻¹; atrazine 500 g L⁻¹; imazapyr 250 g L⁻¹; paraquat 250 g L⁻¹; glyphosate 450 g L⁻¹; clethodim 240 g L⁻¹; amitrole 250 g L⁻¹; and Alliance® (amitrole 250 g L⁻¹ + paraquat 125 g L⁻¹).

The superior treatments in term of overall weed control were an atrazine / paraquat tankmix and most combinations of bromacil and imazapyr with a 2nd knock of paraquat to desiccate excess foliage. The population of annual ryegrass exhibited strong levels of glyphosate and clethodim resistance due to high survival rates following treatment with these herbicides.

One application of paraquat was insufficient to have any impact on ARG potential seed production, however two applications spread 20 days apart improved seed set control dramatically. This treatment did not provide any control of windmill grass.

EXP 4: Controlling windmill grass along fence lines – Nyngan, NSW.

The windmill grass in this experiment was quite advanced in growth stage, having already flowered and set seed. The inclusion of a 2nd knock of paraquat was applied to all chemical treatments, 18 days later, to increase the rate of weed brownout.

Table 5. Control of windmill grass using residual herbicides and a second knock of paraquat.

Treatment	Rate(s) per ha	Windmill grass biomass control (%) 43 DAT	Windmill grass plants per 10 m ² (% control) 7 MAT
bromacil	1 kg	89	5.8 (94)
bromacil	2 kg	98	1.3 (99)
bromacil	3 kg	99	1.7 (98)
bromacil + imazapyr	1 kg + 1 L	99	2.9 (97)
bromacil + imazapyr	1 kg + 2 L	99	4.9 (95)
bromacil + imazapyr	1 kg + 3 L	100	0.0 (100)
bromacil + imazapyr	2 kg + 1 L	99	0.4 (99)
bromacil + imazapyr	2 kg + 2 L	100	0.0 (100)
bromacil + imazapyr	2 kg + 3 L	100	0.0 (100)
bromacil	0.5 kg	70	5.8 (94)
bromacil + amitrole	0.5 kg + 5 L	76	36.7 (64)
bromacil + amitrole	0.5 kg + 10 L	95	16.7 (84)
bromacil + amitrole	1 kg + 5 L	92	7.5 (93)
bromacil + amitrole	1 kg + 10 L	90	4.2 (96)
untreated control	-----	0	100.1 (0)

NOTE: formulation concentrations were: bromacil 800 g kg⁻¹; imazapyr 250 g L⁻¹; amitrole 250 g L⁻¹; and paraquat 250g L⁻¹. Assessments were made 43 DAT for common sowthistle, wild radish and flax-leaf fleabane biomass control (all treatments resulted in 100% control except untreated control). Very dry conditions thereafter did not stimulate any emergence of these weeds. However windmill grass persisted due to its biennial ability and was therefore assessed 7 MAT.

Bromacil applied at rates of 2 or 3 kg ha⁻¹ without tank mixing other herbicides was satisfactory as a residual herbicide. At these rates windmill grass control was maintained in the high 90% range. The addition of imazapyr at 1 L ha⁻¹ to bromacil at 1 kg ha⁻¹ improved control and produced near 100% control of windmill grass 7 months after treatment. This combination of herbicides seems to be the most effective combination for

controlling windmill grass. Mixtures of bromacil (according to Table 5) and amitrole were not as effective as the bromacil/imazapyr combinations; this is because the amitrole did not add significantly to the control in almost all cases compared to the single rate of bromacil at the last assessment.

EXP 5: Controlling annual ryegrass and common sowthistle along fence lines – Coolah, NSW.

The annual ryegrass was not too advanced in this experiment (mid-tillering) and it was decided not to spray a second knock of paraquat to speed up plant brownout.

Table 6. Control of annual ryegrass and common sowthistle using residual herbicides, 2 MAT.

Treatment	Rate(s) per ha	Annual ryegrass % biomass red'n	Annual ryegrass control (0-5)	Common sowthistle per 4 m ²
bromacil	1.5 kg	62.7	3.2	0.0
bromacil	3 kg	92.0	4.3	0.3
bromacil + imazapyr	1.5 kg + 1.5 L	96.0	4.5	0.3
bromacil + imazapyr	1.5 kg + 3 L	98.0	4.8	0.0
bromacil + amitrole	1.5 kg + 5 L	91.0	4.2	0.0
bromacil + amitrole	1.5 kg + 10 L	98.3	4.9	0.7
diuron	1 kg	15.0	1.0	3.3
diuron	2 kg	20.0	1.2	0.3
diuron + imazapyr	1 kg + 1.5 L	85.7	3.8	0.7
diuron + imazapyr	1 kg + 3 L	97.3	4.7	0.7
diuron + amitrole	1 kg + 5 L	78.7	3.3	0.0
diuron + amitrole	1 kg + 10 L	85.0	3.5	2.0
sulfometuron	400 g	87.3	3.8	18.3
glyphosate	2 L	84.7	3.5	8.3
untreated control	-----	0.0	0.0	5.3

NOTE: formulation concentrations were: bromacil 800 g kg⁻¹; imazapyr 250 g L⁻¹; amitrole 250 g L⁻¹; sulfometuron 750 g kg⁻¹; diuron 900 g kg⁻¹; and glyphosate 450 g L⁻¹.

Both bromacil + imazapyr treatments and the diuron + high rate of imazapyr treatment were the best in terms of combined annual ryegrass and common sowthistle control. Sulfometuron had very poor residual control of sowthistle.

Many diuron treatments appeared as effective as bromacil as a treatment against sowthistle. Diuron is used widely in broad-acre cropping to control this weed, as well as fleabane. There are now limitations to its use due to environmental concerns and its use patterns have been limited and regulated.

EXP 6: Controlling fleabane and common sowthistle along fence lines – Tamworth, NSW.

Although there was annual ryegrass in this experiment and it was considered extremely advanced (late tillering and flowering) for residual herbicides to work properly. However, this experiment continued so assessments could be made to measure the emergence of fleabane and sowthistle well after treatment application.

Table 7. Control of fleabane and common sowthistle using residual herbicides.

Treatment	Rate(s) per ha	Fleabane % biomass red'n 1 MAT	Sowthistle seedlings per 10m ² 2 MAT	Fleabane seedlings per 10m ² 2 MAT
bromacil	1.5 kg	41.7	0.0	0.7
bromacil	3 kg	88.7	0.0	0.0
Treatment	Rate(s) per ha	Fleabane % biomass red'n 1 MAT	Sowthistle seedlings per 10m ² 2 MAT	Fleabane seedlings per 10m ² 2 MAT
bromacil + imazapyr	1.5 kg + 1.5 L	86.7	0.7	0.0
bromacil + imazapyr	1.5 kg + 3 L	86.7	0.0	1.0
imazapyr	3 L	73.3	65.3	9.0
bromacil + amitrole	1.5 kg + 10 L	90.0	0.0	0.0
diuron	1 kg	41.7	14.0	70.3
glyphosate + saflufenacil + 2,4-D	1.5 L + 34 g + 500 mL	96.3	63.0	10.0
diuron + imazapyr	1 kg + 1.5 L	71.7	8.0	19.3
diuron + imazapyr	1 kg + 3 L	80.0	2.3	5.0
saflufenacil + imazapyr	34 g + 3 L	93.7	25.3	1.0
diuron + amitrole	1 kg + 10 L	99.0	9.7	0.0
sulfometuron	400 g	53.3	14.7	10.0
glyphosate	1.5 L	80.0	85.7	18.0
untreated control	-----	0.0	17.0	30.7

NOTE: formulation concentrations were: bromacil 800 g kg⁻¹; imazapyr 250 g L⁻¹; amitrole 250 g L⁻¹; sulfometuron 750 g kg⁻¹; diuron 900 g kg⁻¹; 2,4-D 625 g L⁻¹; saflufenacil 700 g kg⁻¹; and glyphosate 450 g L⁻¹.

Applications of bromacil or combined with imazapyr or amitrole had superior control of sowthistle and fleabane.

EXP 7: Controlling windmill grass and common sowthistle along fence lines – Trangie, NSW.

Windmill grass control along fence lines requires the control of the established plants that often survive over winter and recover in warmer months plus controlling the seedling emergence when favourable rains trigger germination. For these reasons, windmill grass is noted as a more stubborn weed to control.

The windmill grass at the time of application was very advanced having already flowered and set seed.

As shown before, bromacil is better than diuron for the residual control of common sowthistle. Diuron did show good control at the highest rate of 2 kg ha⁻¹ for sowthistle but this control declined significantly with the 1 kg ha⁻¹ rate.

This experiment experienced very dry conditions after treatment application and better results were expected. Considering these conditions, control was exceptional especially treatments that comprised at 3 kg ha⁻¹ of bromacil.

Table 8. Control of windmill grass using residual herbicides.

Treatment	Rate(s) per ha	Windmill grass estimated % control 2 MAT	Sowthistle plants per 20m ² 6 MAT
bromacil	1.5 kg	63	1.3
bromacil	3 kg	98	0.0
bromacil + imazapyr	1.5 kg + 1.5 L	65	1.0
bromacil + imazapyr	1.5 kg + 3 L	87	3.7
bromacil + amitrole	1.5 kg + 5 L	80	1.0
bromacil + amitrole	1.5 kg + 10 L	82	1.7
diuron	1 kg	6.7	19.0
diuron	2 kg	12	1.3
diuron + imazapyr	1 kg + 1.5 L	60	25.7
diuron + imazapyr	1 kg + 3 L	75	41.3
diuron + amitrole	1 kg + 5 L	8.3	11.7
diuron + amitrole	1 kg + 10 L	6.7	7.7
sulfometuron	400 g	20	130.7
glyphosate	2 L	8.3	43.0
untreated control	-----	0	66.3

NOTE: formulation concentrations were: bromacil 800 g kg⁻¹; imazapyr 250 g L⁻¹; amitrole 250 g L⁻¹; sulfometuron 750 g kg⁻¹; diuron 900 g kg⁻¹; and glyphosate 450 g L⁻¹.

EXP 8: Controlling feather-top Rhodes grass along fence lines (pre-emergence only)– Tara, QLD.

Feather-top Rhodes grass is an extremely hard plant to control once emerged with resistance to glyphosate making matters worse. The best approach is to find a range of residual treatments to prevent this weed establishing along fence lines.

Table 9. Control of feather-top Rhodes grass using residual herbicides.

Treatment	Rate(s) per ha	Feather-top Rhodes grass plants per 20m ² 2 ½ MAT	Feather-top Rhodes grass per 20m ² 4 ½ MAT
bromacil	1.5 kg	0.3	2.7
bromacil	3 kg	0.0	0.0
bromacil + imazapyr	1.5 kg + 1.5 L	0.0	0.0
bromacil + imazapyr	1.5 kg + 3 L	0.0	0.0
bromacil + amitrole	1.5 kg + 5 L	0.7	0.0
bromacil + amitrole	1.5 kg + 10 L	0.0	1.0
diuron	1 kg	3.0	25.7
diuron	2 kg	4.7	16.7
diuron + imazapyr	1 kg + 1.5 L	0.0	1.3
diuron + imazapyr	1 kg + 3 L	0.0	0.3
diuron + amitrole	1 kg + 5 L	1.7	6.7
diuron + amitrole	1 kg + 10 L	1.3	22.3
sulfometuron	400 g	0.7	13.7
glyphosate	2 L	3.7	19.3
untreated control	-----	1.3	8.3

NOTE: formulation concentrations were: bromacil 800 g kg⁻¹; imazapyr 250 g L⁻¹; amitrole 250 g L⁻¹; sulfometuron 750 g kg⁻¹; diuron 900 g kg⁻¹; and glyphosate 450 g L⁻¹.

The data above indicates that the only two active ingredients that were effective against feather-top Rhodes grass were bromacil and imazapyr because diuron or diuron + amitrole treatments failed to control this weed.

DISCUSSION

There is an industry need to develop treatments for better fence line and road side management of weeds. Although glyphosate has long been the preferred option, glyphosate resistance in many weed species has threatened this practice.

It appears the best combination of herbicides for the weeds tested in these trials is the mixture of bromacil at 1-1.5 kg ha⁻¹ and imazapyr at 1 L ha⁻¹. These herbicides complement each other's weed control spectrum. The imidazolinone herbicides, such as imazapyr are known for their excellent efficacy on grasses and relatively poor longer term control of thistles and fleabane. However, bromacil has been shown to provide good control of grasses, while demonstrating excellent longer term control of surface germinating weeds such as common sowthistle and fleabane. Therefore, the combinations

of these two herbicides represent an excellent longer term control option for grasses and surface germinating broad-leaf weeds. However, this combination of herbicides is best applied to weeds either as a pre-emergence or early post-emergence treatment. Once weeds have grown beyond the 20cm height stage, an application of paraquat is recommended to promote the speed of brownout.

More research is planned over the next three years to investigate more herbicides and combinations. One group of herbicides will receive more attention, namely, herbicides from Group G mode-of-action group as some have registered uses as residual herbicides. Also, there may be some other herbicides that were once used over 30 years ago that may have some utility in this area and require testing.

It is important to note that effective fence line and road side weed management does not have to involve using herbicides to bare the soil for complete control of all species. Herbicides could be used to selectively control some plant species so as to use the competitive effects of more desirable species in these areas (a more integrated approach). Although this aspect is not the scope of the current project, it may be investigated in the future.

ACKNOWLEDGEMENTS

This research was co-funded by NSW DPI and GRDC under projects UA00124 & UQ00080 and we acknowledge the technical assistance from Greg Brooke and Rebecca Miller from NSW DPI. None of this work would have been possible if not for the generous contributions of people that allowed access to their sites.

REFERENCE

Preston, C. (2017). The Australian Glyphosate Sustainability Working

POST FLOOD SURVEILLANCE FOR AQUATIC WEEDS THE HOW, WHY, AND WHEN

Charlie Mifsud

NSW Aquatic Weed Project Officer, NSW Department of Primary Industries, Grafton,
NSW 2460. Email: charles.mifsud@dpi.nsw.gov.au

SUMMARY Flooding events are a major pathway for the spread of aquatic weeds. During the winter of 2016 tributaries of the Murray-Darling River system in New South Wales and Queensland experienced flood events. Within 6 to 12 months after similar floods in these same waterways in 2011 – 2012, several new aquatic weed infestations were discovered. These included alligator weed in the Namoi and Peel Rivers; alligator weed in new locations in the Wah Wah irrigation district; and water hyacinth in the Dumaresq River.

Given the experience of 2011 – 2012, and with the knowledge that one known infestation of water lettuce in a waterway adjacent to the Dumaresq River was inundated by flood waters, planning was initiated to undertake post- flood surveillance to locate and eradicate any new infestations. The plan involved surveillance of waterways and an education and awareness campaign to be undertaken from the spring of 2016 to the summer of 2017 – 2018.

Surveillance was undertaken on high risk waterways in the Murray-Darling catchment that had known or previous infestations of aquatic weeds including the Dumaresq, Namoi and Peel Rivers and waterways in the Griffith City Council and Carrathool Shire Council regions including Barren Box Swamp, Mirrool Creek and flood channels in the Wah Wah irrigation district. Surveillance was undertaken by weeds professionals using all-terrain vehicles, boats, drones, helicopters and a dog trained in the detection of alligator weed.

An advertising and awareness campaign through local newspapers, recreational fishing clubs, the Country Women's Association and Landcare was also used to increase awareness of aquatic weeds. Although surveillance continues, no new infestations have been located. However, it is important to stay vigilant and to respond rapidly to new incursions, given such weeds can rapidly expand and cause major impacts to waterways once established.

Keywords: Aquatic weeds, surveillance, floods

INTRODUCTION

Water is a known pathway for the spread of invasive weeds with seeds and vegetative material moved readily by water. Extreme events such as floods can lead to the movement of significant quantities of vegetative material over long distances and the disturbance of existing habitat removing native vegetation and soil cover, allowing weeds to establish easily.

This is not just an issue in Australia, with flooding in January 1997 in the Truckee River drainage system in the United States of America being associated with the spread of several weeds including the aquatic weed Eurasian water milfoil into areas where they were not previously recorded (Donaldson 1997).

In New South Wales (NSW), many waterways in the Murray-Darling catchment are free from aquatic weeds and their introduction could have serious detrimental consequences to the environmental, economic and recreational value of these waterways. Several new infestations of aquatic weeds have become established in recent years and are undergoing eradication campaigns. Many of these were discovered within 6 – 12 months after floods in 2011 – 2012, where it was thought that aquatic weeds had spread from dams and other waterways into rivers and creeks by these flood events. Many of these weeds discovered are Weeds of National Significance and have recently had NSW Biosecurity Zones declared or are listed in Regional Strategic Weed Management Plans. This is due to their ability to rapidly spread and increase in abundance, causing substantial impacts in a relatively short period of time.

The aquatic weeds, infestation locations and associated flooding events from 2011 – 2012 are presented in Table 1 and include:

A significant flood was experienced in the Dumaresq River in January 2011. The subsequent discovery of water hyacinth occurred in September 2011. It was presumed that this weed was washed out of a farm dam during the January flood. A rapid response was then undertaken to prevent the spread and to eradicate the infestation.

Alligator weed was discovered in the Namoi River in April 2012. A flood event was experienced in the Peel and Namoi Rivers in November 2011. The source of the alligator weed was discovered in Sandy Creek, a tributary of the Peel River. It is thought that the flood event in 2011 spread alligator weed plants out of Sandy Creek into the Peel and Namoi Rivers.

A new alligator weed infestation was discovered in a flood channel in the Wah irrigation area in Carrathool Shire in February 2013. A flood event was experienced in this area in March 2012. The spread of alligator weed in the channel has been associated with existing alligator weed infestations upstream in Barren Box Swamp.

Table 1. Flood events and relationship to aquatic weed infestations.

Flood Date	Waterway	Aquatic Weed	Date of Finding
January 2011	Dumaresq River	Water hyacinth	September 2011
November 2011	Namoi River	Alligator weed	April 2012
March 2012	Wah Irrigation District	Alligator weed	February 2013

During the winter of 2016 areas of NSW and Queensland received substantial rainfall leading to flooding in tributaries of the Murray-Darling River system. Given the experience of 2011 – 2012, and the fact that a known infestation of water lettuce was inundated by flood waters of the Dumaresq River, planning was initiated to undertake post-flood surveillance to identify and eradicate any new aquatic weed infestations.

Unfortunately, the water lettuce infestation found in the waterway adjacent to the Dumaresq River only occurred in March 2016 just prior to the flooding event. This infestation was thought to have germinated from dormant seed from a previous water lettuce infestation in the Dumaresq River between 2006 –2010. This infestation was considered potentially eradicated until the new infestation was located.

There may also be aquatic weed infestations in farm dams and backyard ponds in Queensland and NSW that could be washed into waterways in the Murray-Darling River system in flood events. This has previously occurred in the Dumaresq River with water lettuce in 2006 and water hyacinth in 2012.

The above events highlighted the need to stay vigilant for the possible spread of aquatic weeds and the need to respond rapidly to new incursions. This is to prevent rapid expansion of range and is particularly important in this area given that there are several aquatic weed infestations in waterways in upper tributaries of the Murray-Darling River system. These have the potential to spread significant weeds through floods further into tributaries of the Darling River situated in NSW. These include: salvinia in Dogwood creek near Miles, water lettuce in the Warrego River near Cunnamulla, water lettuce in the Goondiwindi sewage ponds and water hyacinth in Horse creek near Meandarra.

Given the above, a proactive and rapid surveillance plan was developed and implementation commenced by NSW Department of Primary Industries and a number of local council staff following the 2016 flood events. This paper is an outline of the progress to-date.

MATERIALS AND METHODS

The plan involved surveillance of waterways and an education and awareness campaign to be undertaken from the spring 2016 to summer of 2017 – 2018. Surveillance was undertaken by weeds professionals using one or more of the following methods: surveillance of the banks and surface of waterways by walking, all-terrain vehicles, boats, drones, helicopters and a dog trained in the detection of alligator weed. The type of method varied with the waterway, personnel available and aquatic weed being surveyed.

The Dumaresq River and associated waterways involves surveillance primarily for the floating aquatic weeds water hyacinth and water lettuce. The Dumaresq River is the border with NSW and Queensland and surveillance in this waterway involves cross- border cooperation between staff from agencies in both states. Methods used to undertake surveillance in these waterways include the use of aerial surveillance via helicopters and drones as infestations of floating aquatic weeds are easily seen from the air. Ground-

truthing of possible infested sites was then undertaken by personnel on foot. All-terrain vehicles were also used in areas unsuitable for aerial surveillance.

In the Namoi Valley and the Wah irrigation district alligator weed surveillance was undertaken by walking areas considered to be of high risk of infestation such as creek and river banks, irrigation channels and floodways. In the Namoi and Peel Rivers, surveillance for alligator weed has also involved the use of watercraft such as kayaks and boats. The use of a dog trained in the detection of alligator weed has been trialled in the Namoi Valley to assist human surveillance.

To assist the surveillance efforts in the Dumaresq River an advertising campaign through local newspapers in the Inverell, Tenterfield and Moree Plains Shire Council areas was undertaken in the autumn of 2017. This campaign over six weeks involved a weekly quarter page advertisement on water lettuce and water hyacinth.

Recreational fishing clubs, the Country Women's Association and Landcare were all contacted to increase awareness of aquatic weed issues in these high priority areas. The awareness of recreational fishing clubs to aquatic weeds was increased via the use of promotional material supplied to the clubs and via displays of aquatic weeds at fishing events. The Country Women's Association distributed aquatic weed awareness material to their members via their e-news column and through emails.

RESULTS AND DISCUSSIONS

There were no reports of water hyacinth or water lettuce in the Dumaresq River despite the advertising campaign undertaken in newspapers in the autumn of 2017. However, the campaign to raise awareness of aquatic weeds within the Country Women's Association, Landcare and recreational fishing clubs is ongoing.

Surveillance in parts of the Dumaresq River involving the use of all-terrain vehicles in the winter of 2017 found no aquatic weeds. Ongoing treatment of the known water lettuce site near the Dumaresq River and surveillance of nearby waterways will continue to 2018. Aerial surveillance with a helicopter originally scheduled for autumn 2017 was delayed due to inclement weather and the need to ensure all staff were appropriately trained in helicopter procedures. The helicopter surveillance and use of the drone was rescheduled for the spring and summer of 2017 – 2018.

Due to the increase in the amount of alligator weed detected in the Peel and Namoi Rivers in 2016 increased surveillance by teams on foot and in water craft as well as the use of a detector dog was undertaken.

Surveillance and awareness campaigns are continuing as it is important to stay vigilant and to respond rapidly to new incursions of aquatic weeds, given their ability to rapidly infest a waterway after a spread event.

REFERENCE

Donaldson, Susan G (1997) Flood-borne Noxious Weeds: Impacts on Riparian Areas and Wetlands. California Exotic Pest Plant Council 1997 Symposium Proceedings.

ILLEGAL ONLINE TRADE OF NOXIOUS WEEDS IN AUSTRALIA: MONITORING AND REGULATING E-COMMERCE

Zachariah Munakamwe1 and Angela Constantine2

¹Lead Biosecurity Officer Detection (High Risk Invasive Plants), Agriculture Victoria, PO Box 3100, Bendigo, Victoria 3552, Australia.

Email: zachariah.munakamwe@ecodev.vic.gov.au

² Biosecurity Manager (High Risk Invasive Plants), Agriculture Victoria, PO Box 5646, Cranbourne, Victoria 3977, Australia.

Email: angela.constantine@ecodev.vic.gov.au

SUMMARY The rapidly expanding online trade (e-commerce) is a relatively new worldwide biosecurity challenge and it is increasingly becoming a major noxious weed pathway. The Victorian government through Agriculture Victoria initiated a project to monitor and address this emerging pathway for early detection of State prohibited weeds (SPWs), the highest category of noxious weeds in the State. This paper discusses the online marketplace as it relates to an emerging pathway for the trade of noxious weeds. In 2016/17 (to 20 March 2017), there was a total of 26 detections of water hyacinth (*Eichhornia crassipes* (Mart.) Solms) and salvinia (*Salvinia molesta* D.S. Mitch.) being sold online in Victoria, New South Wales (NSW), Western Australia, South Australia and Queensland. Victoria had the highest number of detections (42%), followed by NSW (31%). No online detections were recorded for Tasmania, the Northern Territory and the Australian Capital Territory in this period. The importance of public awareness and stakeholder engagement in managing this pathway is also discussed.

Keywords: biosecurity, eBay, pathway, salvinia, water hyacinth.

INTRODUCTION

Humans have transported and traded plant and animal species for millennia (Hulme 2009), but new challenges have arisen from the growth in popularity of online trading in recent years (Riefa 2007). This expanding new market place has become a major platform for illegal trade of noxious weeds. In response, the Victorian government through Agriculture Victoria developed a project to address this emerging noxious weed pathway aiming to:

- Stop or reduce State prohibited weeds being accessed through online sources.
- Educate the public on the risk that these species pose and why they should not be sourced.
- Engage key stakeholder platforms and develop mitigation strategies.

This paper describes monitoring to detect SPW trade through active surveillance and regulation through law enforcement, and initiatives such as key stakeholder engagement, public education, and passive surveillance networks.

Background

This project was based on an online trade and biosecurity scoping done by Agriculture Victoria in 2014. State prohibited weeds (SPWs) are the focus of this work as they are the highest category of declared noxious weed in Victoria, and are managed with the aim of eradicating them from the State. SPWs are either not yet present in Victoria, or are only present in small infestations that are considered to be eradicable from the State. It is illegal to buy, sell or transport State prohibited weeds in Victoria (*Catchment and Land Protection Act* 1994). Prevention, detection and early intervention is outlined as goal number one on the Australian Weeds Strategy 2017 to 2027 (Invasive Plants and Animals Committee 2016).

The online market place

The e-commerce market is diverse (Hinsley *et al.* 2016), easily accessible and recognised as a significant pathway for the introduction of pest species into new areas, posing a huge biosecurity risk. This marketplace is vast and highly interconnected through groups that often share common memberships. Information spreads easily through these networks. This project focussed on three major online sites where SPWs are most commonly detected in trade; eBay (www.ebay.com.au), Gumtree (www.gumtree.com.au) and Facebook (www.facebook.com). Understanding how these websites operate was essential to determine how to influence them.

eBay

eBay is the leading online trading website in Australia. The website is free to buyers, but sellers are charged for selling items. eBay collects a substantial amount of information from users and nearly all transactions can be traced, because communications generally occur through the site.

Gumtree

Gumtree has been owned by eBay since 2005, and has an online classified style of sales. Gumtree has an extensive social media presence on Twitter and Facebook and uses social media to communicate news and information. Buyers contact sellers directly, off-site by phone or email. Minimal information is collected on Gumtree making transaction tracing nearly impossible.

Facebook

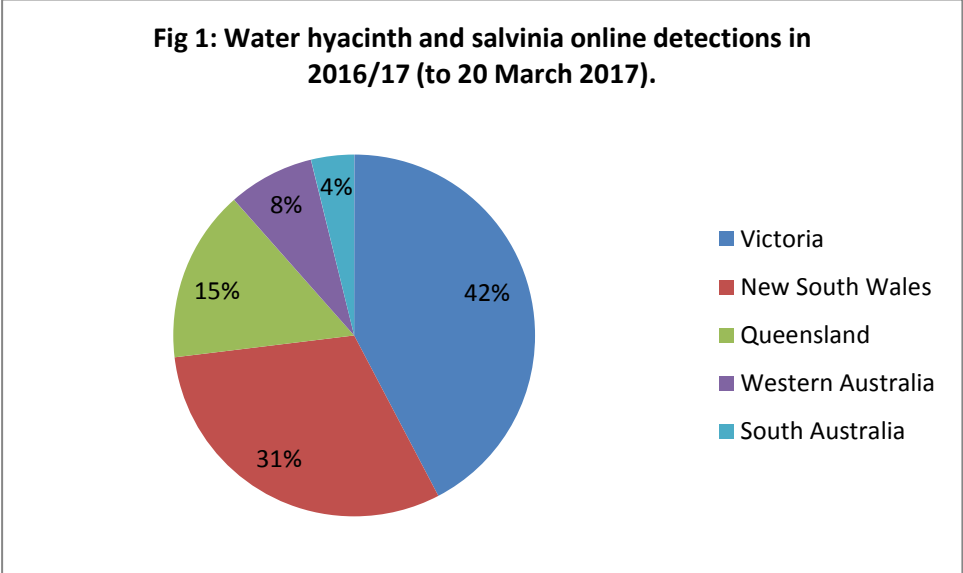
Facebook is an online social networking service with over 1.39 billion monthly active users (Sangi *et al.* 2016) and over 40 million small businesses (Hinsley *et al.* 2016). Users register to participate and can join common-interest user groups. These common-interest user groups, particularly the Buy, Sell and Swap Free, are increasing in popularity and are becoming a major noxious weed pathway in Victoria.

RESULTS AND DISCUSSIONS

Online detections and law enforcement

Alerts were set on eBay.com.au and gumtree.com.au search engines to trigger an email message whenever an SPW was listed on the websites. Key words were set for each SPW species, as were other phrases that are commonly found associated with SPW sales, such as ‘pond plants’, ‘water lilies’ and ‘water plants’. Random manual searches were also conducted on the two websites and on Facebook particularly under the “Plants for sale” category.

In 2016/17 (to 20 March 2017), there was a total of 26 online detections of the SPWs water hyacinth (*Eichhornia crassipes*) and salvinia (*Salvinia molesta*) in five states; Victoria, New South Wales, Western Australia, South Australia and Queensland (Table 1). None of the other species of Victorian SPW were detected. Victoria had the highest number of these online detections (42%) followed by NSW (31%) (Fig 1). No online detections were recorded for Tasmania, the Northern Territory and the Australian Capital Territory.



Once a SPW is detected in trade in Victoria, Agriculture Victoria officers follow up with enforcement activities including seizing and destroying all plants present. About 840 water hyacinth plants were seized at a property in Warracknabeal following a detection on a local Buy, Swap and Sell group on Facebook. Sixty-eight water hyacinth plants were seized at a property in Rupanyup. A total of 52 water hyacinth plants were seized on two properties in Bendigo following a detection on a local Garden Swap, Buy and Sell group on Facebook. About 300 water hyacinth plants were seized at a property in Dandenong following a detection on Gumtree.

All interstate detections were forwarded to counterparts in the respective jurisdictions. *Ad hoc* searches resulted in several SPW hits from overseas, mostly from the United States of America and Europe. No further action was taken on these detections as these were beyond this project’s scope.

Table 1. State prohibited weed detections, 2016/2017 (to 20 March 2017).

Plant species	Website	Victoria	New South Wales	Queens -land	Western Australia	South Australia	Total
Water hyacinth	Gumtree	5	7	1	2	1	16
	Facebook	6	0	0	0	0	6
	EBay	0	0	0	0	0	0
Salvinia	Gumtree	0	1	3	0	0	4
	Facebook	0	0	0	0	0	0
	EBay	0	0	0	0	0	0
Total		11	8		2	1	26

4

Online public education

Raising awareness through public education (Derraik and Phillips 2010) can be effective in stopping or reducing illegal trade of noxious plants. The majority of noxious weed trade offences occur unintentionally due to poor knowledge of biosecurity legislation, misidentification of species and poor labeling (Derraik and Phillips 2010). Nearly all the alleged offenders investigated under this project expressed ignorance of noxious weeds and the associated legislation. An article on water hyacinth was therefore released to the media following the Bendigo detections to educate the public on the risks that this species poses and why it is illegal to trade. The article was also posted on Agriculture Victoria Facebook page and website. Public education is vital for the early detection and eradication of SPWs (Munakamwe 2014), and the internet can be a powerful tool to disseminate such information (Invasive Species Advisory Committee 2012).

Key stakeholder engagement

Besides public education, Derraik and Phillips (2010) reported that it is also necessary to liaise with those in charge of online trading sites to increase awareness. Under this project Agriculture Victoria strives to engage key stakeholders and build sustainable relationships in an effort to influence the marketplace. For example there are plans to negotiate with eBay to incorporate an improved pop up article on their website warning users that it is illegal to trade noxious weeds.

Passive surveillance

Agriculture Victoria maintains an active network of trained volunteers (Weed Spotters) who help with passive surveillance and reporting of State prohibited weeds. In 2016/17 (to 20 March 2017), three water hyacinth online detections were prompted by Weed Spotter

reports. There are currently 2503 registered Weed Spotters on the Agriculture Victoria database.

Conclusion

Invasive plants continue to enter and establish in Victoria through a variety of pathways, including intentional legal or illegal and accidental importation. Agriculture Victoria embarked on this project to combat an emerging pathway in this ever-growing biosecurity challenge. Significant results have been realised so far.

ACKNOWLEDGEMENTS

Special thanks to Mark Watt, Nigel Ainsworth, Mark Sellwood and Andrew Staley for their valuable contributions.

REFERENCES

Derraik, J.G.B. and Phillips, S. (2010). Online trade poses a threat to biosecurity in New Zealand. *Biological Invasions* 12,1477 – 1480.

Hinsley, A., Lee, T.E., Harrison, J.R. and Roberts, D.L. (2016). Estimating the extent and structure of trade in horticultural orchids via social media. *Conservation biology* 30 (5), 1039 – 1047.

Hulme, P. E. (2009). Trade, transport and trouble: managing invasive species pathways in an era of globalization. *Journal of Applied Ecology* 46, 10 – 18.

Invasive Plants and Animals Committee (2016). Australian Weeds Strategy 2017 to 2027, Consultation draft. Australian Government Department of Agriculture and Water Resources, Canberra.

Invasive Species Advisory Committee (2012). Invasive Species and E-commerce. United States Department of the Interior.

Munakamwe, Z. (2014). Understanding the biology and ecology of poverty weed (*Iva axillaris* Pursh) – A guide towards eradication and control programs in Victoria. *Plant Protection Quarterly* 29 (3), 117 – 119.

Riefa, C. (2007). “To Be or Not to Be an Auctioneer?” Some Thoughts on the Legal Nature of Online “eBay” Auctions and the Protection of Consumers. *Journal of Consumer Policy* (2008) 31, 167 – 194.

Sangi, N., Shuguang, L. and Samad, P.A. (2016). Comparative analysis: A case study of Facebook and Renren. *Science international: Lahore* 28 (6), 5097 – 5104.

EDUCATION ENFORCEMENT AT THE FLEMINGTON FLOWER MARKETS, SYDNEY

Emily Kaye McCarthy

Biosecurity Weed Officer, Strathfield Council, New South Wales

65 Homebush Road, Strathfield NSW 2135

Emily: Emily.McCarthy@Strathfield.nsw.gov.au

SUMMARY

The cut flower industry at the Sydney Flower Markets has a captivating atmosphere that can be described as unique and bizarre. It might be the mix of early morning, the aroma of fresh flowers, cakes and coffees or the 1,000 forklifts buzzing around, but the sense of enthusiasm is never dull. Double this with an annual turnover exceeding \$150 million and accounting for 75% of the cut flower trade in New South Wales (NSW)²² one would anticipate the Sydney Flower Market is a perfect place to purchase non – invasive floral material. Unfortunately this isn't necessarily the case! How did the florist industry lose touch of their environmental responsibility and the potential impacts this is having on the natural environment? From June 2016- June 2017 Strathfield Council conducted 92 routine inspections at the Sydney Flower Markets. These inspections vary from Monday to Sunday and from 4am to 11am. During these inspections the staff at Strathfield Council are not only undertaking compliance but also providing educational material and having discussions around the topic of noxious weeds.

INTRODUCTION:

With an annual turnover exceeding \$150 million and accounting for 75% of the cut flower trade in NSW²³ one would anticipate the Sydney Flower Market is a safe place to purchase non – invasive floral material for the perfect bouquets and floral displays. Unfortunately this isn't necessarily the case! It can be exposed that invasive noxious weed species have been harvested, imported and sold on a daily basis via the Sydney Flower Markets.

In 2014 the Flower Markets were identified by the Regional Weeds Committee as a potential weed hotzone and a high risk pathway. Strathfield Council was encouraged to apply for funding under the Weed Action Program (WAP) to employ a dedicated weed officer to monitor compliance directly at the Flower Markets. Since then Council has also worked to educate stall holders about the *Noxious Weed Act 1993* and the current *Biosecurity Act 2015* and *Biosecurity Regulation 2016* addressing the adverse impacts of the weeds for sale.

²² Sydney Markets Limited (SML), (2015). [Our Markets, World-Class Markets](http://corporate.sydneymarkets.com.au/about-us/our-markets.html)
<http://corporate.sydneymarkets.com.au/about-us/our-markets.html> (Accessed 7th June 2017)

²³ Sydney Markets Limited (SML), (2015). [Our Markets, World-Class Markets](http://corporate.sydneymarkets.com.au/about-us/our-markets.html)
<http://corporate.sydneymarkets.com.au/about-us/our-markets.html> (Accessed 7th June 2017)

The purpose for which species are sold varies; the use or purpose of sale is a key accelerator in the distribution of the weed. For example species such as *Ligustrum lucidum* is primarily sold for the aesthetic value of the mature berries while *Asparagus* species such as *Asparagus macowanii* are utilised for the sole purpose of the foliage.

The risk that each species poses is a dynamic framework including the location in which the species was sourced, the purpose of the sale and the legal standing of the weed. This paper explores not only the risk that these species pose but also the attitudes of the people responsible for the sale and distribution of species identified as weeds via the cut flower industry in Sydney.

THE SOURCE

How did this professional industry lose touch of their environmental responsibility and the impacts this is having on the natural environment? This requires insight into the availability of weeds being utilised for sale. For example where are the weeds coming from? What makes them so desirable for the floral industry?

The major source of weeds that are sold at the markets comes from wild harvesting. This is the practice of using what the environment presents, hence the harvesting of weeds in natural areas such as parks, reserves and national parks. This method creates a demand for the species and encourages 'pickers' to promote the growth of the weed and support the source by means of nurturing the infestation. A lot of the stall holders at the flower markets struggle to correctly identify the weeds being sold at their stall. Hence Strathfield Council has been working to educate stall holder on how to identify different species and what is and isn't a weed in NSW.

The second major source of weeds at the flower markets are the weeds that are propagated on small scale farms that are generally owned by the stall holders themselves. One example includes a family run business that provides 90% of the *Salix matsudana* supply at the markets. This family run business owns several acres of farm land in the Sydney basin some of which is dedicated to the production of *Salix matsudana* (tortured or curly willow). According to the family concerned they have been doing this now for over 40 years and nobody has ever had a problem before.

Lastly there is also a strong supply of noxious weeds that enter NSW via the cut flower industry from other states. The majority of the weed foliage sold at the markets comes from farms in Queensland and Victoria. This foliage is brought in via delivery trucks and air transport and is packaged in sealed boxes. Very rarely is this material seen with viable propagules, it is generally just bunches of greenery/foliage. While working with the stall holders, the council has emphasised the importance of these species being notifiable weeds and highlighting the importance and potential risk of interstate trade.

Over the past 18 months Strathfield Council has been gathering information on different suppliers in both the Sydney area and interstate. The council has also been working with

the stall holders to find alternatives to these invasive species; unfortunately the major challenge to find alternatives is the cost benefit. There is no substitute for free material harvested in the wild.

INDUSTRY & TIMELINE:

The cut flower industry at the Sydney Flower Markets has a captivating atmosphere that can be described as unique and bizarre. It might be the mix of early morning, the aroma of fresh flowers, cakes and coffees or the 1000 forklifts buzzing around, but the sense of enthusiasm is never dull. With a strong European background many stall holders have English as second language. Hence with all this organised chaos, the presence of a weed officer carrying out inspections is not necessarily welcomed with open arms. Consequently there are hurdles even before the conversation has started. Strathfield Council adopted a strategy in mid-2015 to first eliminate all major threats of spread from the species being sold. Initially any species being sold with mature seed was eliminated from sale and was deemed unacceptable. This didn't take long to be adopted by the stall holders, but it also did not mitigate the risk completely. For example those stall holders selling *Asparagus aethiopicus* (sprengeri) were asked what was happening to the red berries now that only green berries were being sold? One stall holder gladly replied with well I pick them off and rebury them? This was a red flag regarding the strategy. It was then that council moved to ban all weed species with material that can propagate. This worked well for some time with a few hiccups along the way. One example would be the seasonal changes and the trends eg. the sale of *Ligustrum lucidum* (broad leaf privet) in the autumn months. Along with good faith compliance was also some non-compliance that was identified via reports from other helpful stall holders. This was quickly addressed with undercover officers posing as florist and requesting material such as Pampas grass stems *Cortaderia species*. The word soon got out and afterwards the stall holders were reporting a reduction in material at least from what they could see.

The stall holders were also asked to submit possible strategies they believed would mitigate the risk of spread from the weeds they were selling. A lot of entries highlighted the idea of continuing sale of weed species without viable material that could propagate on the plant. Consequently the idea of devitalised *Salix matsudana* developed. Stall holders claimed this was already in place and all stems had been dipped in herbicides adequately. Strathfield Council then took a random sample from one of the largest supplier of the species to investigate if *Salix matsudana* would grow. After only one week the nursery staff at Strathfield Council found the stems initiating tiny white roots. These continued to grow for another four weeks before council brought it to the stall holder's attention.

THE FLORIST:

'Nobody in my area checks my shop' This quote was what one council officer heard many times when first attending the markets. Council could educate and lecture the stall holders but the supply won't stop till the demand is decreased. 'It will make the bride happy, she wants trailing' is another quote that was stated numerous times - doing it for the bride. The

truth is the florist wants to provide for the bride at the lowest price with the biggest mark-up which provides a strong incentive to use cheap species such as road side weeds. Unfortunately education isn't always the issue. Certificate holding florists complete a component about noxious weeds in their training. Therefore they are making an informed choice to fill a bouquet with weeds. This comes back to the bottom line that these weeds are readily available and inexpensive to harvest or propagate. There is no substitute for free. This makes councils jobs harder requiring more inspection of florists, more weed removals and more education to the general public to make an informed choice when purchasing a bouquet.

CONSULTATION AND PLANNING:

Between June 2016 and June 2017 Strathfield Council conducted 92 routine inspections at the Sydney Flower Markets, these inspections ranged from Monday to Sunday 4am to 11am. During these inspections staff are not only undertaking compliance but also providing education material and discussion around the topic of noxious weeds. Along with inspections multiple meetings have also taken place over the last two and half years with stalls holders at the Markets, NSW Department of primary Industries (DPI) Local Land Services (LLS) and weeds committees. The first meeting was held 15th September 2015. A working group was formed to discuss species such as *Ligustrum*, *Salix* and *Asparagus*. A meeting was then held in July 2016 - this was to discuss the strategy that Strathfield Council had prepared for a 6-12 month phase out period for weeds concerned. It was stated that the only exemption would be if DPI was to issue a permit for the sale of weeds. In this meeting the introduction of the *Biosecurity Act 2015* was also discussed. In January 2017, DPI sent refusal letters to all permit applicants. This sparked some very angry stall holders who requested a meeting with DPI. Thirteen stall holders attended a further meeting in March 2017. After much discussion the group came to the decision that stall holders would be given a further three months of non-compliance for the species requested in permit applications. This linked up with the proposed implementation of the *Biosecurity Act 2015* in July 2017. During this time stall holder were to look for alternatives or spend time preparing mitigation protocols to the DPI to demonstrate species such as *Salix* could be potentially safe to sell. During this 3 month period, Officers again from the Council, DPI and LLS met at the Sydney Flower Markets and spoke with stall holders regarding the *Biosecurity Act 2015* and their responsibilities. During this meeting (14th June 2017) stall holders were told that due to lack of mitigation protocols received, Strathfield Council would be going ahead with full compliance under the *Biosecurity Act 2015*. This sparked stall holders concerns! The stall holders communicated that they would make contact with the Minister's office to take this further.

CONCLUSION:

At the time of writing this paper, the DPI Strathfield Council and the Flower Growers Association were meeting to determine if there are effective measures to mitigate the risk of spread of invasive species being sold through the Markets. Potentially there could be a narrow range of species approved, with strict condition of production and sale. Strathfield

Council will implement this program at the Markets using extension, awareness and compliance programs if necessary. The overall goal is the reduction of sale of weed species but also to encourage the stall holders to stop spending time in finding loop holes for the legislation and instead to invest time into alternative species. The direct risk of this action is the threat of black market sale. Strathfield Council will continue with routine and surprise inspections, undercover officers and late night & early morning examinations. Nonetheless there is no stopping the couriers. Much like pizza delivery there is nothing preventing a person ordering weeds direct from their florist.

ACKNOWLEDGEMENTS:

Strathfield Council Staff
Department of Primary Industries
Regional Weeds Committee
Local Land Service
Sydney Markets Limited.

REFERENCE:

Internet Article:

Sydney Markets Limited (SML), (2015). Our Markets, World-Class Markets
<http://corporate.sydneymarkets.com.au/about-us/our-markets.html> (Accessed 7th June 2017)

PUBLIC AWARENESS: BUILDING WEED AWARENESS IN THE COMMUNITY

Karen Jenkin

Authorised Officer, Hawkesbury River County Council

INTRODUCTION

Hawkesbury River County Council has been serving the community since 1948. Council was initially formed to keep the Hawkesbury River and its tributaries free of Water hyacinth. We are a single purpose County Council with our goal being to administer weed control throughout our council areas of Blacktown, Penrith, Hawkesbury and the Hills Shire. There are 8 weed control County Councils in NSW today.



Figure 1: Hawkesbury River County Council area

I started with HRCC in 2006, temporarily filling in for the administration officer who was on a year's maternity leave. Within a few months of taking phone calls from unhappy neighbours I had quickly developed an interest in weeds and the impact they had on our environment.

The year went quickly and when my position was up, management asked me to stay on as the grants officer and assistant to the then Operations Manager. This is when I decided to study, and completed my Certificate 2 and 3 in Conservation and Land Management. I then applied for a vacant Weeds Inspector's position with council, and was fortunate enough to win that position.

IN THE BEGINNING

It became very clear to me when I started conducting private property inspections, that there was very little knowledge of prohibited weeds, let alone that there was a Council that manages them!

We knew that we needed to get our name and purpose out amongst our community, it was at this point that I started to look at what public awareness activities we engaged in.

The only events we attended were our constituent Council yearly shows. These are great shows, but at the end of the day people are more interested in fairy floss, show bags and rides, rather than learning about weeds...

WHERE TO FROM THERE

Initial brainstorming came up with the idea of setting up a weed awareness table in shopping centres, with a live weed display and brochures. Some comments on this initiative include:

- As we were not selling anything and it was for community awareness, the table hire was free.
- It was more cost-effective than attending weekend shows as our presence in the centres was within work hours, so there was no over time necessary.

The shopping centres were good, we did speak to a lot of people but people were out shopping, so they were more interested in buying Boneseed than going home to rip them out of their gardens.

After deliberating with my new Operations Manager, we decided that we should focus on people that are interested in the environment, plants and their gardens. I then contacted my four council's community event coordinators to find out what events would suit our targeted audience.

I started to consider other avenues and venues for council to promote our weed message. Places like Homemaker centres, Flower power, Masters and Bunnings, these venues have events and groups such as Spring Garden Days and Garden Clubs.

The more people I spoke to at these days the more events I started to get invited too, such as TAFE open days, World Environmental Days, National Tree Days and then each of my 4 council areas started having yearly Sustainability Events.

We even had an afternoon with the Royal Horticultural Society of NSW, speaking to the floral art club about roadside weeds and what they can and cannot use in their floral designs. One of my plants I had on display was rather large climbing asparagus fern, a favourite in bridal bouquets, button holes, floral arrangements and decorations.



After the talk I was having a cup of tea and a chat when a lady came up and asked to speak to me privately. We walked away from the group and she handed me an envelope and said “this is for the Asparagus fern when you leave could you put it next to the blue bmw”. In the envelope was \$600 !!! I was shocked and if I could do was laugh and shake my head, gave her back the envelope and said nice try. Just demonstrates the distance that some people will go to.



THE FLOW ON EFFECTS

All the events we were participating in lead us to smaller community and group talks. One interesting talk was with a company called Little Angels Family Day Care Services. I met the facilitator at Blacktown Show and she asked if I could be a guest speaker at their monthly meeting. I had around 45 home owners who looked after children in their homes all very interested as to what they should and shouldn't have in their gardens. More than half the room were growing either Green cestrum, Privet or African Olive, so this talk generated quite a few inspections.



Table 1: List of event conducted from 2015 - 2017

2016-17

Shows and Exhibits attended	Date	People spoken to
Penrith Home Show	23-24 July	185
Hawkesbury Nursery	30-Jul	126
Annangrove Enviro Center	30-Jul	94
Ebenezer Arts & Craft	13-Aug	81
Penrith Show	27-28 Aug	151
Wetlands Symposium	16-Sep	154
Orange Blossom Festival	17-18 Sept	346
Catch a Carp Woodcroft	28-Jan	32
Bunnings Castle Hill	9-Feb	70
Luddenham Show	18-19 Feb	164
McLeod Park	2-Mar	143
McDonald Valley Community Day	4-Mar	45
Blacktown Show	18-19 March	123
Hawkesbury Library	6-Apr	43
Castle Hill Bromeliad Society	8-Apr	48
Earth Day Nurranginy	22-Apr	54
Bowen Mountains Fair	29-Apr	32

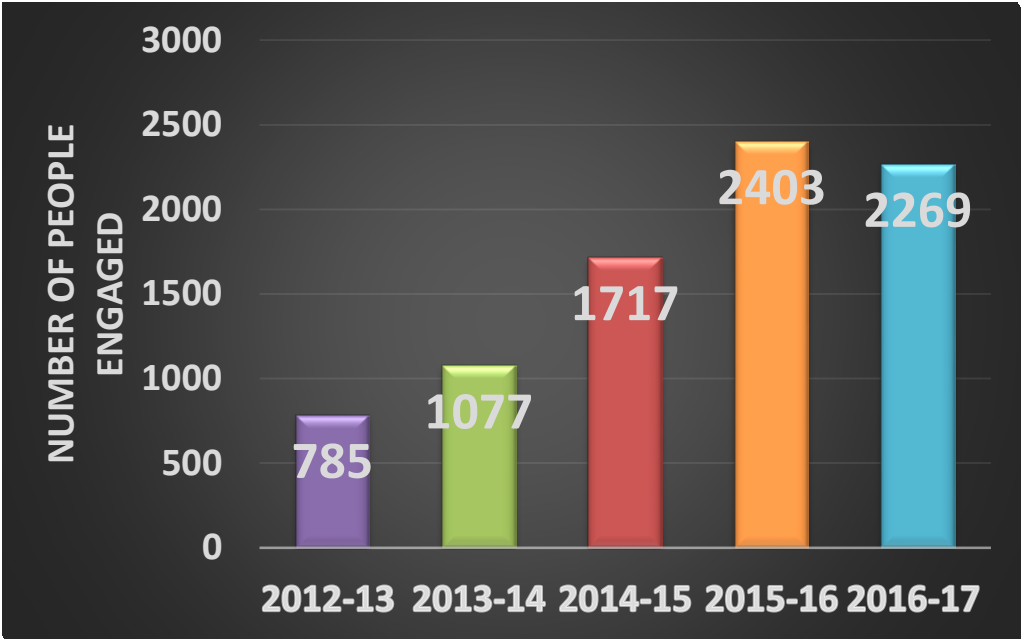
2015-16

Shows and Exhibits attended	Date	People spoken to
Annangrove Enviro Center	18-Jul	35
Bunnings Michinbury	8-9 Aug	167
Penrith Home Show	22-23 Aug	203
Penrith Show	29-30 Aug	153
Blacktown Enviro Show	26-Sep	138
Tafe Open Day Richmond	17-Oct	94
Kingswood High School		
Agriculture Gala Day	18-Nov	448
Woodcroft Catch a Carp Day	30-Jan	178
Luddenham Show	20-21 Feb	192
Castle Hill Show	4/5/6 March 2016	234
Blacktown Show	2-3 April	196
The Royal Horticultural Society of NSW	27/04/2016	54
Hawkesbury Show	15,16,17 April	336
Wetlands Olympic Park	28-Apr	52
Little Angels Child Care	22-May	33
Bowen Mountains Fair	28-May	60
Annangrove Enviro Center	2-Jun	32

HOW THE NSW WEEDS ACTION PROGRAM (WAP) INFLUENCED OUR EVENT

When the Weed Action Program came into effect it enabled HRCC to develop a Public Awareness Program and over the past 5 financial years we have jumped from 6 to 19 events per year. We also purchased counters to record how many people we spoke to and to basically see what events worked better than others.

Table 2. Number of People engaged each year



Last year we lost Castle Hill Show due to the redevelopment of the showground which reflects in the chart numbers. We did manage to pick up 2 other community events to bring last year’s total to 19 shows. Castle Hill Show was always fun, loads of interested avid gardeners, some would say too avid. I remember about 3 years ago I spoke with one lady about Mother of Millions, her English was quiet poor but she was fascinated and loved her succulents and kept asking me where she could purchase them, it took me some time to explain to her that you couldn’t buy them, I’m not for selling them and that they are not allowed to be in her garden... 2 hours had past and I was speaking to another patron when out the corner of my eye I could see the same lady pulling out plantlets from my Mother of Millions pot and putting them into her pocket!! As soon as she realised I was onto her she took off and I had to race after her to recover the plantlets and again explain, but as soon as I mentioned the law and possible fines she got the point.

The funding from the WAP program has enabled council to develop:

- localised weed information such as these identification brochures to add to the other Primefacts and Grow me Instead booklets
- Utilise the design and produce supplied of resources developed by NSW DPI under the NSW No Space for Weeds campaign on early detection “Look out for weeds”

With so many good resources and limited table space we made up show bags full of resources. We needed to ensure people could still see the real thing - people love to see live plants.



We were introduced to the wrapped car at the 2013 Weeds Conference:



And one year later....



THE HRCC WEEDS MOBILE WAS BORN

Under the NSW No Space for Weeds – “Look out for weeds” campaign a car wrap design was made available. HRCC invested in this for one of our cars -I feel this has been one of

our greatest public awareness wins. Yes, this is my take home vehicle, and yes, I get stopped everywhere!

There is not a week that goes by that someone hasn't stopped me and ask for advice or wanted to know "what's the name of that plant". I have been stopped at traffic lights and people have driven up next to the car and asked for my business card. Or I have looked into my rear-view mirror and have seen the passenger from the car behind taking a photo of our details that are on the back-windscreen.

The increased contact with our community really started to show results, as more landholders were seeking advice and wanting to organise property inspections from council staff. This was a first for council as this level of community engagement had previously not been achieved in such numbers.

It was at this point that council started to refine and offer property weed management plans to landholders.

Date: 19/06/2017 Name: _____ Property: Old Northern Rd, Dural NSW 2158

WEED MANAGEMENT PLAN (HRCC)			
Area/Zone	Weeds	Techniques	Completion Dates
Mixed native vegetation / weed populations	Narrow-leaf privet (<i>Ligustrum sinense</i>), Broad-leaf privet (<i>Ligustrum lucidum</i>), Lantana (<i>Lantana camara</i>) & Blackberry (<i>Rubus fruticosus</i>)	The use of machinery is permitted to control dense areas of weeds. Identify all native vegetation prior to commencing weed control, prevent damage to identified native vegetation. Isolated plants are to be cut at ground level and the stump immediately treated with herbicide.	27/07/17
Whole of treatment zone	Narrow-leaf privet (<i>Ligustrum sinense</i>), Broad-leaf privet (<i>Ligustrum lucidum</i>), Lantana (<i>Lantana camara</i>) & Blackberry (<i>Rubus fruticosus</i>)	Weed species will regenerate from untreated stumps and this regrowth will need to be treated with herbicide when the regrowth reaches 1 metre. Use Brush-off, Grazon extra or Round up Biactive to spray these weeds.	27/09/17
HRCC Inspection	Project oversight	HRCC inspection staff will conduct site inspections at 3-month intervals with you being present, to assess WMP progression and make adjustments where necessary.	27/10/17

Weed management plans are issued by HRCC authorised officers to landholders as an agreement to conduct weed control on lands that have been given an **individual biosecurity direction under the NSW Biosecurity Act 2015, section 129** or, are affected by weed growth. They are a binding contract between council and the landholder to carry out weed control in a prescribed manner, and within an agreed timeframe. The weed management plan clearly states what weed species are to be treated, by which method, and by which date these works needs to be completed.

The weed management plan (**biosecurity undertaking**) is solely directed at management of weed infestations and does not provide the landholder with any permission to disturb native vegetation, or change landform through broad scale soil disturbance.

In the instance of conjecture from a local council or government agency, and pertaining to weed control being carried out on a property under a weed management plan (i.e. damage to native vegetation communities, or specific threatened species), the plan may be suspended and reviewed by the concerned parties to overcome legitimate environmental issues.

I, _____, of Old Northern Road, Dural, accept this Weed Management Plan (**biosecurity undertaking, NSW Biosecurity Act 2015**) and agree to implement the plan in accordance with the dates herein.

Signature of Owner _____ Date _____

Name of Authorised Officer _____ Date _____

Signature of Authorised Officer _____ Date _____

Council's property weed management plans are a personalised strategy for the landholder to control weeds on their property - and includes; identification of weed issues, maps of weed infestations on the property, relevant control practices, a weed control calendar and a range of suggested herbicides, if applicable.

Council schedules follow up visits with the landholder, as a mentoring service to build their weed control capacity, and provide basic demonstrations on common weed control techniques.

CONCLUSION

Council is pleased with the results of the HRCC weed awareness campaign. We believe that our community has benefited from the increased opportunity to interact with our staff, learn essential skills such as weed impact, identification and control as well, knowing that there is a point of contact for people to get unbiased, professional information on all things weed related.

At the end of the day the more people we educate, the more eyes we have out in the environment to help us do a better job.

REARING BIOLOGICAL AGENTS FOR CONTROLLING THREE WEED SPECIES IN NSW

Update on the biocontrol agent rearing and release program at the Grafton Primary Industries Institute

Troy R.F. Brown

Technical Officer (Weeds), NSW Department of Primary Industries
Grafton Primary Industries Institute, Trenayr Road, Junction Hill, NSW, 2460
Email: troy.brown@dpi.nsw.gov.au

SUMMARY The New South Wales Department of Primary Industries are managing a biocontrol rearing and release program at their Grafton based insectary. The current focus for biocontrol at the facility is to maintain healthy and vigorous biological agent cultures and provide public access to biocontrol agents, via local and state government agencies, for the management of targeted weeds in NSW. The program currently breeds biocontrol agents intensively for managing three target weed species including *Salvinia molesta* (D.S.) Mitchell (salvinia), *Dolichandra unguis-cati* (L.) Lohmann (cat's claw creeper) and *Anredera cordifolia* (Ten.) Steenis (Madeira vine). This paper provides an update on rearing systems utilised for biocontrol agent production at Grafton. Also included is a brief discussion in relation to funding arrangements and program governance.

Keywords: Insects, Biology, Nursery, Insectary.

INTRODUCTION

The weeds biological control program at Grafton is managed by the New South Wales Department of Primary Industries (NSW DPI) for the purposes of providing public access to biological control agents (agents) for managing weeds in NSW. The program is funded via a consortium arrangement consisting of representatives from local and state government and other interested landholders. This consortium is called the NSW Weeds Biocontrol Taskforce. The NSW DPI relies on annual taskforce member subscriptions to maintain the operation of this service and aims to provide access to the agents as requested.

The NSW DPI operates within the guidelines of a special permit issued by the NSW Government under the repealed Noxious Weeds Act 1993. This permit allows staff to grow, store and/or move noxious weed material (including from Queensland), as agent host plants, for education, research and biocontrol agent rearing purposes.

The agents are utilised as a complimentary management option for managing weeds including three Weeds of National Significance; cat's claw creeper, Madeira vine and salvinia. Biocontrol agent rearing and release techniques are refined for the purposes of optimising environmental weed management. The data and information generated is collated and analysed to identify successful agent colonisation techniques and weed impact potential. NSW DPI staff work closely with taskforce members in a coordinated approach and encourage integrated pest management principles for targeting key weed infestations across NSW.

METHODS

There are three agents under intensive production for controlling three weed species at the Grafton Primary Industries Institute (GPII). These include:

- *Hylaeogena jureceki* Obenberger (Coleoptera: Buprestidae) (jewel beetle) for managing cat's claw creeper
- *Plectonocha correntina* Lacordaire (Coleoptera: Chrysomelidae) (Madeira beetle) for managing Madeira vine
- *Cyrtobagous salviniae* Calder and Sands (Coleoptera: Curculionidae) (salvinia weevil) for salvinia

The agents are reared under semi-controlled conditions at the GPII insectary. Each agent displays a unique biology and therefore requires different rearing systems. For example both the Madeira beetle and jewel beetle are flying insects hosted by a terrestrial vine and are reared within specifically designed insect rearing cage systems. Both the adults and larval instars feed on the foliage before pupating for a period of time then emerging as adult insects.

Salvinia is a sterile floating water fern and the larvae of the weevil feed within the rhizomes of the plant (Julien *et al.* 1987). The rhizomes are mostly submersed in water and therefore require a ponding system for rearing. Seasonal variability in temperature and humidity influence agent productivity. Therefore monitoring host plant health and environmental conditions within the insectary are vital so that adjustments to the rearing systems can be made as necessary for optimising agent productivity.

Salvinia Weevil

The salvinia weevil rearing production system at GPII consists of four x 14,000L outdoor ponds. An additional two x 6,000L and eight x 2,000L ponds are stocked with uninfected salvinia in order to provide a clean fresh source of food to maintain the culture as required.

The salvinia weevil is released for deployment into the field as an inoculant in conjunction with live salvinia plant material. The infected plant material is collected directly from the Grafton insectary, packaged within 45L sealed plastic tubs that hold approximately 9kg of fresh salvinia each. The fresh salvinia inoculant can contain an average of around 60 weevils/larvae per kg of fresh plant material (Nachtrieb 2012). These agents are sent to a variety of locations around NSW.

Salvinia Weevil Releases

An estimated total of up to 1,800kg of inoculated salvinia can be released across ≥ 25 sites across NSW in any 12 month period. At an average rate of 60 weevils/larvae per kg of salvinia, this equates to approximately 108,000 weevils & larvae released over any given 12 month period.

All reports continue to be positive with regards to biocontrol of salvinia, particularly in the Northern Rivers region but also the Hawkesbury/Nepean river system (Stanfield 2013). Given the increased demand for accessing this agent, plans are underway to expand production at the Grafton facility.

Jewel Beetle

Jewel beetles are reared under two separate systems at GPII. One is a caged system where 12 x eight inch potted cat's claw creeper plants are stocked to host 100 jewel beetles on an eight week rotation. The second system is an outdoor system and consists of a series of benches stocked with potted cat's claw creeper plants. The outdoor system provides an opportunity for the beetles to select optimum micro habitats around the facility and allows them to roam freely between each host.

A jewel beetle rearing harvest assessment was carried out for the January 2016 to June 2017 period from the caged system and results were variable throughout this period.

The data suggests that the warmer months from spring through to summer are most productive (unpub. data). It should be noted that only maximum temperature was controlled within the glasshouse facility (27 - 30 C) and humidity was not controlled in that period. To maximise productivity of this agent within a caged system, it is advised that this species should ideally be reared under controlled climatic conditions (night temperature: 20 C, day temperature: 27 C; relative humidity 65%; photoperiod: 12 h dark: 12 h light) (Dhileepan *et al.* 2013).

Between January 2017 and June 2017 a total of 465 individuals were harvested from the cage system. In that same period 2,390 adult beetles were harvested from the outdoor system. Although the outdoor potted system resulted in higher harvest yields compared to the cage system, the caged system is important to maintain a constant population size. The cage system effectively preserves the breeding population genetic diversity by reducing risk associated with exposure to extreme environmental variation and predation.

Jewel Beetle Releases

A total of 15 field releases containing a total of 2,320 beetles were made from January 2016-June 2017 period. Further releases of this agent are planned for the 2018/19 period targeting key sites. A monitoring program is also underway to assess colonisation and weed impact in the field post release.

Madeira Beetle

Madeira beetles are reared at GPII within purpose made insect rearing tents. The tents are held within a semi-controlled glasshouse environment, maximum temperature is controlled at 27 - 30 C. As with the jewel beetle system, minimum temperature and relative humidity is not controlled. The tents are usually stocked with 10-12 trays of vigorously growing Madeira vine trained along small trestles to host the beetles during their breeding cycle. Up to 100 Madeira beetles are added to the Madeira vine stocked tents at establishment and the entire life cycle is complete after about 40-50 days (Snow *et al.* 2012). Each tent produces on average 578 beetles. During the 2016/17 period the facility operated at full capacity with about 14,000 beetles collected from January 2016 to June 2017. Productivity tended to be higher late winter/early spring & late summer/early autumn.

While host plants are generally more tolerant to variation in temperature and humidity, the Madeira beetles tend to be more sensitive to these changes and require more stable conditions for optimal productivity (*pers comm.* Dr Kunjithapatham Dhileepan). Extremely high temperatures over the 2016 Christmas period resulted in a significant decline in pupal survival, with glasshouse temperatures reaching >50 C. This may have impacted genetic

diversity of the population and to counteract this, plans are in place to collect beetles from historic release sites to infuse with the current breeding population.

Madeira Beetle Releases

A total of 7,500 beetles have been released onto 20 key Madeira vine infestations across NSW sites from January 2016 to June 2017. Demand for this agent has increased however production capacity is somewhat limited. Like with the jewel beetles, there are more releases planned at strategically identified infestations across NSW. A monitoring program is underway to assess colonisation and weed impact at key release sites.

DISCUSSION

The objective of biological control is not to eradicate but to reduce a weed's density to non-economic levels (Julien and White 1997). Biological control should be used as part of an integrated approach which can only truly be achieved through good collaboration. The objective of the NSW Biocontrol Taskforce is to facilitate collaboration by incorporating biological control as an additional tool for managing weeds in NSW. Although the GPII facility is somewhat limited in terms of production, there is potential to expand. The taskforce is always seeking new members and participation is encouraged to all those interested in sustainable weed management. Biocontrol agents for the abovementioned weeds are available, and can be provided by contacting the author.

ACKNOWLEDGEMENTS

Thanks to Rodney Ensbey for reviewing this paper, Rodney Ellem and Paddy Stanton for general rearing facility assistance. Rous County Council, Hawkesbury Environment Network, North Coast Local Land Services, Tamworth City Council, Mid-Coast Council, Clarence Valley Council, Bernadette Hanley, Dr Kunjithapatham Dhileepan and Mrs Elizabeth Snow for providing insect rearing advice, NSW Biocontrol Taskforce for funding support. The Taskforce receives a variety of funding including from the NSW Weeds Action Program, National Parks and Wildlife Service, and a variety of Local Land Services and local governments.

REFERENCES

- Dhileepan, K., Taylor, D.B.J., Lockett, C. and Treviño, M. (2013). Cat's claw creeper leaf-mining jewel beetle *Hylaeogena jureceki* Obenberger (Coleoptera: Buprestidae), a host-specific biological control agent for *Dolichandra unguis-cati* (Bignoniaceae) in Australia. *Australian Journal of Entomology* 52, 175-181.
- Julien, M.H., Bourne, A.S. and Chan, R.R. (1987). Effects of adult and larval *Cyrtobagous salviniae* on the floating weed *Salvinia molesta*. *Journal of Applied Ecology* 24, 935-944.
- Julien, M. and White, G. (1997). Biological control of weeds: theory and practical application. ACIAR Monograph No. 49 192pp.
- Nachtrieb, J.G. (2012). Rearing the salvinia weevil for biological control of giant salvinia at the U.S. Army Corps of Engineers Lewisville aquatic ecosystem research facility, pp. 13-24. In A. Knutson and J. Nachtrieb (eds.), A guide to mass rearing the salvinia weevil for biological control of giant salvinia. Texas A&M AgriLife Extension Service, Special Publication ESP-475. http://cise.tamu.edu/media/355740/gs_manual_10-15-12.pdf
- Snow, E.L., Palmer, W.A. and Wilmot Senaratne, K.A.D. (2012). The release of *Plectonycha correntina*, a leaf feeding beetle for the biological control of Madeira vine. Conference proceedings from the Eighteenth Australasian Weeds Conference, pp. 339-342, Perth, Australia.

Stanfield, C. (2013) The use of biological control agents to manage *Salvinia molesta* within the Hawkesbury/Nepean river. Conference proceedings from the Seventeenth NSW Weeds Conference, pp.30-32, Cowra, NSW, Australia.

Weeds in Australia, (2017). *Managing Weeds*. [online] Available at: <http://www.environment.gov.au/biodiversity/invasive/weeds/management/biological-control.html> [Accessed 10 July. 2017].

SPREAD OF INVASIVE GRASSES INTO NAMADGI NATIONAL PARK

Steve Taylor¹, Jenny Conolly²

¹ACT Parks & Conservation Service, 500 Cotter Rd Weston 2611 ACT
Senior Invasive Weeds Officer, Biosecurity & Rural Services
Email: Steve.Taylor@act.gov.au

²Transport Canberra & City Services, 500 Cotter Rd Weston 2611 ACT,
Invasive Species Officer, City Services
Email: Jenny.Conolly@act.gov.au

ABSTRACT Namadgi National Park is 110,575ha, comprising nearly half of the ACT. The eastern boundary of the national park adjoins both rural and peri-urban lands. The western boundary adjoins NSW: Brindabella National Park, Bimberi Nature reserve and rural lands which adjoin Yaouk Nature Reserve and Kosciuszko National Park. African lovegrass, Chilean needle grass and serrated tussock are invasive plants in SE Australia. African lovegrass and Chilean needle grass are abundant and widespread in the ACT's urban areas, along adjacent waterways and increasingly found along rural roads. As a result, spread into Namadgi National Park along the eastern boundary is now a frequent occurrence. There are also large infestations of serrated tussock and African lovegrass on ACT and NSW rural properties that adjoin southern borders of the national park, which are another pathway for spread of invasive grasses. Mowing has been the main cause of the rapid spread of African lovegrass and Chilean needle grass in urban areas, roadsides and along trails. Mowing or slashing along rural roads has created new infestations within the national park. Mapping data from ArcGIS On-line-Collector app shows that current control resources are not adequate in containing the spread.

Key words: mapping, Collector app, ArcGIS On-line, Australian Alps, Namadgi National Park, invasive grasses, invasive plants

INTRODUCTION

Nassella neesiana (Trin. & Rupr.) Barkworth (Chilean needle grass) and *Nassella trichotoma* (Nees) Hack. ex Arechav. (serrated tussock) are Weeds of National Significance (WoNS) due to the damage they cause to the environment and agriculture (VDPI 2007 & 2008). *Eragrostis curvula* (Schrad.) Nees (African lovegrass) is an aggressive invader (Richardson et al 2016).

All three invasive grasses match the definition of invasive species in

Hui *et al* (2017), that is: “alien species [exotics or non-indigenous natives] that sustain self-replacing populations over several life cycles, produce reproductive offspring, often in very large numbers at considerable distance from the parent and/or site of introduction”. Invasive species are a subset of naturalised species, as not all naturalised species become invasive. The terms invasive weed and invasive grass used in this paper follows this definition for invasive species.

The impact of these invasive species is measured using the Environmental Impact Classification of Alien Taxa (EICAT), outlined in Hui *et al* (2017). All three invasive grasses have EICAT ratings of ‘massive’ in the ACT region (based on the worst recorded cases). This translates to altered community composition and irreversible changes in ecosystem functioning in the worst recorded cases.

All three of these invasive grasses are widespread to the east of Namadgi National Park (NP). Specifically, African lovegrass (ALG) is dominant along large stretches of the Murrumbidgee River corridor, adjoining suburbs and rural lands (Butler 1998 and Sharp 2011). ALG has become widespread across Canberra’s urban areas due to mowing practices. Chilean needle grass (CNG) has also been spread in urban areas from poor mower hygiene and incorrect mowing patterns. It is becoming more common across the urban area. ALG and serrated tussock (ST) are widespread to the south east of Namadgi NP on rural properties.

With such large infestations of ALG, CNG and ST on or near Namadgi NPs borders, it was inevitable that spread into the national park would become a major issue. Mapping data from the Collector app (Esri 2017) confirms the increasing frequency of new infestations in the national park. Another invasive weed, sweet vernal grass (*Anthoxanthum odoratum* L.), is also becoming more frequent in Namadgi NP. However its impact is lower than CNG, ST and ALG, so it is not discussed below. Eddy (2016) has produced a thorough review of sweet vernal grass management to help limit its spread.

MATERIALS AND METHODS

The Collector app which syncs with ArcGIS On-line is used to map weed control and new infestations. Table 1 shows a significant increase in the spread of ST in the south-eastern part of Namadgi NP. The source is shown in the Collector app screenshots at Figure 1. Figure 2 shows spot sprayed ST.

Table 1. Spread of Serrated Tussock in the Naas Valley, Namadgi National Park

Financial year	Infestation area (ha)	Southwards spread from source infestation (km)
2012-13	16	4
2016-17	58	21

Source: ArcGIS On-line & Collector app treated weeds feature layers ACTPCS

Figure 1. Serrated Tussock Spread into Namadgi National Park

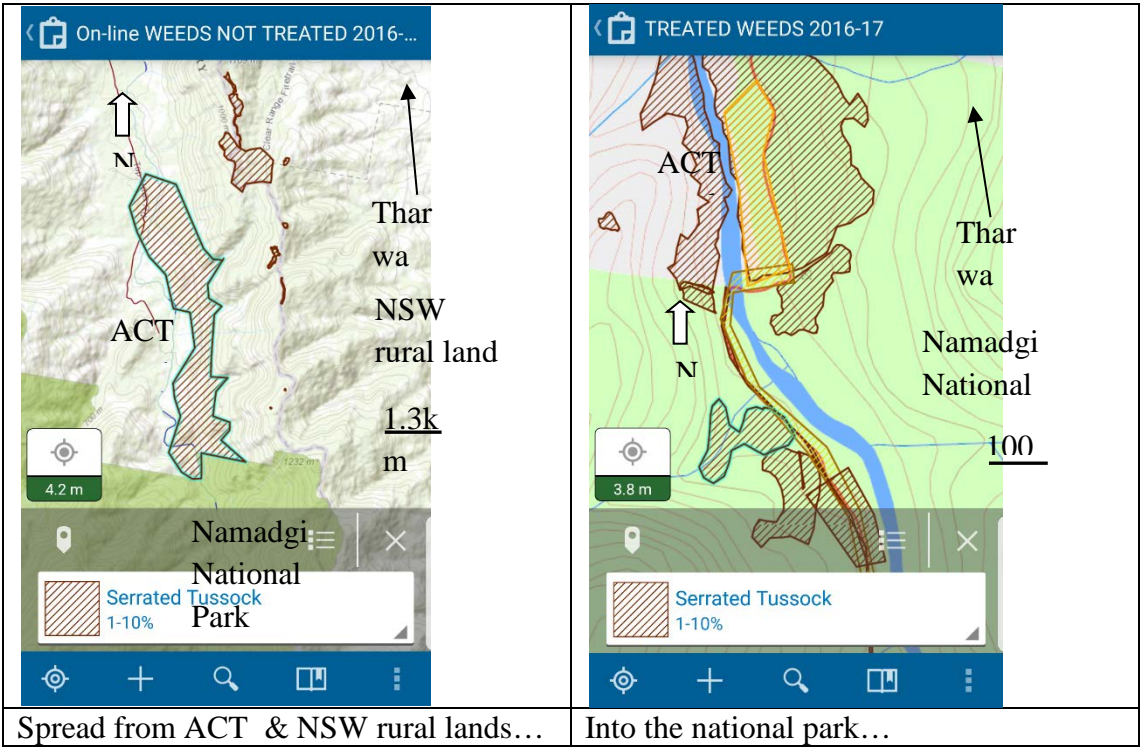


Figure 2. Spot Sprayed Serrated Tussock in Namadgi National Park



Table 2 shows that there has been an exponential increase in ALG infestations in the Orroral Valley of Namadgi NP. Park visitors, vehicles and roadside slashing are the main causes of spread. CNG is also showing signs of rapid spread.

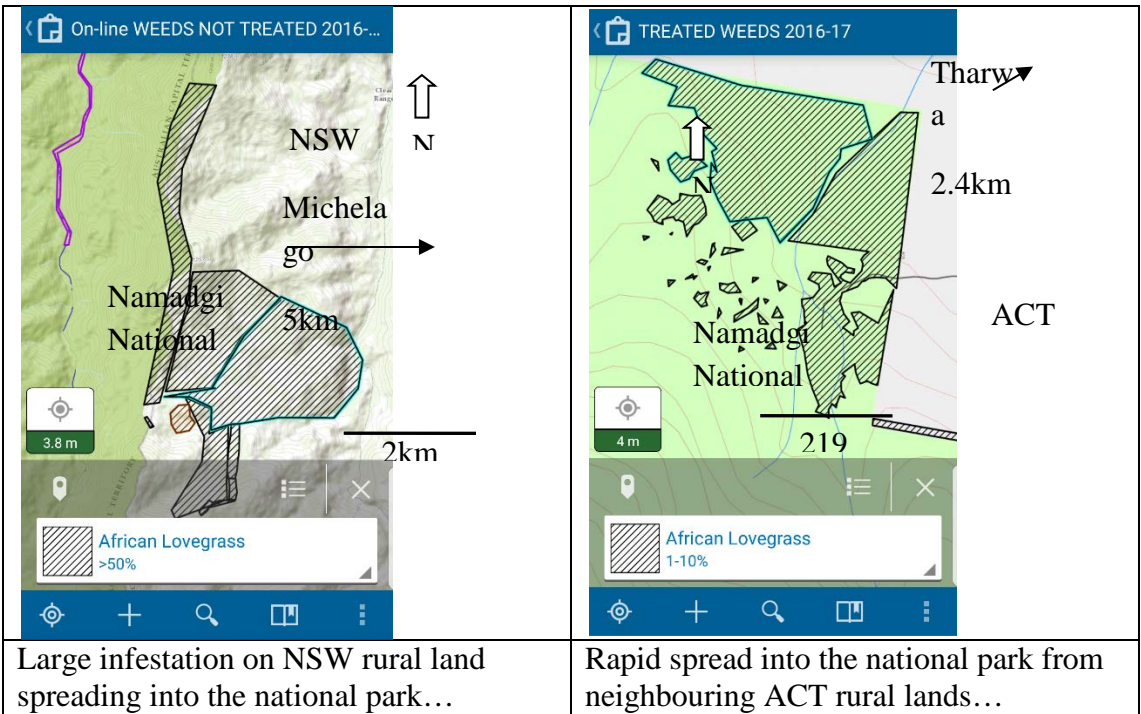
Part of Namadgi NP’s eastern border is adjacent to major infestations of ALG. Figure 3 shows one such infestation in NSW on the Clear Range. There are also extensive infestations on the nearby Murrumbidgee and southern suburbs.

Table 2. African lovegrass & Chilean Needle grass in Orroral Valley, Namadgi NP

Financial year	Number of control sites	
	African lovegrass	Chilean needle grass
2012-13	0	0
2014-15	3	1
2016-17	13	4

Source: ArcGIS On-line & Collector app treated weeds feature layers, ACTPCS

Figure 3. African lovegrass Spread into Namadgi National Park



The other Collector app screenshot in figure 3 shows the rapid rate of spread of ALG once an infestation takes hold. Rapid spread of ALG and CNG along roadsides has been caused by lack of mower hygiene and incorrect mowing patterns. Figure 4 illustrates this for CNG. There is so much urban land heavily infested with CNG and ALG that accidental spread into the national park by visitors and their vehicles is happening more often.

DISCUSSION

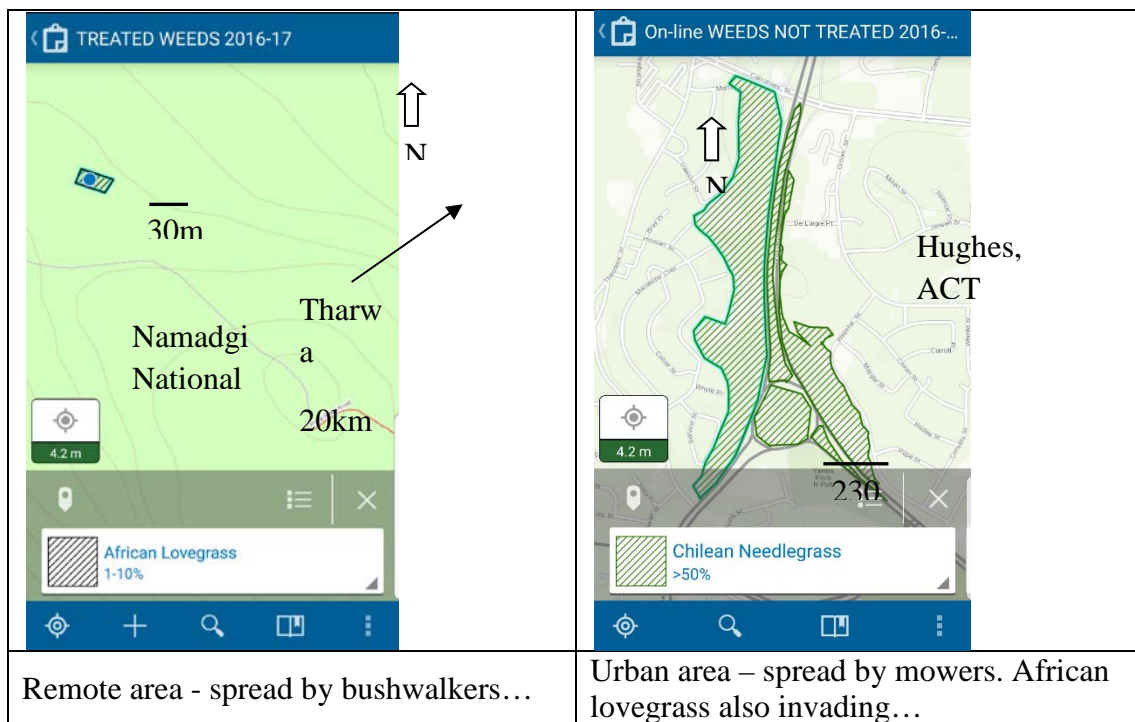
The trend in the mapping data is clear. Current management will see large areas of Namadgi NP invaded by ALG, ST and CNG. The following changes are needed:

- Cease the frequent mowing of roadside kangaroo grass and red grass.
- Do not mow invasive grass infestations when in seed.

- Introduce one strip mowing or slashing on rural roads rather than road to fence. At least one month before the spring mowing, spot spray the invasive grasses with fluproponate & glyphosate. Areas requiring boom spraying with fluproponate should not be slashed. ALG areas will need follow-up control in autumn.
- Augment seed banks with *Bothriochloa macra* (Steud.) S.T.Blake (red grass) which is relatively resistant to low rates of fluproponate.
- Boost invasive grass search and destroy work at high risk areas.
- ALG infestation areas need twice yearly search and destroy work.
- Information at trail heads & car parks as part of an awareness campaign.
- Rural grants to assist property owners with ALG and ST control.

It is essential that these changes are made before the invasive *Hyparrhenia hirta* (Coolatai grass) arrives in the ACT. This herbicide resistant invasive weed, spreads rapidly with mowing, and is near the ACT border.

Figure 4. Spread of African lovegrass & Chilean needle grass



The cost of restoring land that has been long invaded by invasive grasses is extremely high. This has been shown at ‘offsets’ sites in Canberra. If invasive grasses are allowed to spread unchecked in Namadgi NP, the impact on biodiversity will be catastrophic and control costs will be enormous.

ACKNOWLEDGMENTS

Many thanks to the dedicated rangers and field officers of Namadgi National Park and the specialist weed contractors, for their invasive grass control efforts. Without this work such invasive weeds would have spread even further across the Namadgi landscape. Thank you also to rural services officer, Chris Condon; and Landcare officer, Sally McIntosh, for encouraging rural landholders to undertake serrated tussock control.

REFERENCES

Butler, G (1998) Strategy for the Management of African lovegrass in the Murrumbidgee River Corridor, G. Butler Wamboin November 1998

Eddy, D. (2016) A discussion of the biology, distribution, potential invasion and control of Sweet Vernal Grass (*Anthoxanthum odoratum*) in the ACT. David Eddy Ecological Consulting Berridale NSW, March 2016

Esri (2017) Collector for ArcGIS <http://www.esri.com/products/collector-for-arcgis>

Hui, C. and Richardson D.M. (2017) Invasion Dynamics, Oxford University Press

Richardson, F.J, Richardson R.G., Shepherd, R.C.H (2016) Weeds of the South-east: an identification guide for Australia. 3rd edition R.G and F.J Richardson 2016

Sharp, S. (2011) Distribution and Abundance of African Lovegrass in the ACT and Capital Region and Options for Strategic Control: Report to the Southern ACT Catchment Group, December 2011

Victorian Department of Primary Industries VDPI (2007) National Best Practice Management Manual, Chilean needle grass

Victorian Department of Primary Industries VDPI (2008) National Best Practice Management Manual, Serrated Tussock

WATER HYACINTH MAPPING IN GWYDIR WETLANDS USING REMOTE SENSING TECHNIQUES

Rajendra L. Shilpakar¹, Jean Xiaojing Li², Linlin Ge², Peter Dawson¹, Sara Chapman¹

¹ North West Local Land Services; ² University of New South Wales

Email: rajendra.shilpakar@lls.nsw.gov.au

ABSTRACT Invasive weeds such as Water hyacinth are a risk to the social and economic wellbeing of the North West region of NSW. Remote Sensing techniques can be an effective and low cost approach for regular surveillance of invasive weeds across large landscapes. North West Local Land Services (LLS) jointly with the University of New South Wales (UNSW) explored the potential application of a two stage remote sensing technique for accurate mapping of invasive weeds species across a large landscape. Firstly, this research project tested a Landsat remote sensing technique for identifying potential weed incursion areas. Secondly, a drone sensing technique was applied within the potential incursion area identified by the Landsat image analysis for refining the weed distribution map. North West LLS and UNSW applied this two-step remote sensing concept for Water hyacinth mapping in the Gwydir Wetlands Conservation Area. This paper summarizes the conceptual framework and discusses preliminary results of the project.

Keywords: Water hyacinth, Remote Sensing, Spectral signatures, Landsat, Drone sensing.

INTRODUCTION

Wetlands play an important role in purifying water by filtering out and storing pollutants in their sediments, soils, and vegetation. The natural ability of wetland systems to filter water has been used to treat wastewater from industry and mining as well as sewage (Revenge and Tyrrell 2016). Aquatic weeds in freshwater ecosystem, estuarine, and floodplain habitats decrease biodiversity, threaten critical habitat, alter nutrient cycles, and degrade water quality. In particular, Water hyacinth (*Eichhornia crassipes*) is an aquatic plant, which can live and reproduce floating freely on the surface of fresh waters or can be anchored in mud. It is particularly suited to tropical and sub-tropical climates and has become a problem plant in many areas including the Gwydir Wetlands, a wetland of international importance (Ramsar site). As a result, research activity concerning control (especially biological control) of Water hyacinth has boomed up in the last few decades (Albright *et al.* 2004; Malik 2007).

Remote sensing provides a synoptic solution for monitoring aquatic weed infestations over large spatial areas. To be successful, a remote sensing approach must be accurate, repeatable over space and time, and account for the inherent spatial and environmental heterogeneity of a system. Early studies concluded that Water hyacinth and hydrilla (surfaced) could be remotely distinguished in colour infrared video imagery obtained on several dates at widely separated sites in south and southeast Texas (Everitt *et al.* 1999). At this stage, Water hyacinth was mapped with modest accuracies with a mixture of field survey and remote sensing (e.g. Hestir *et al.* 2008).

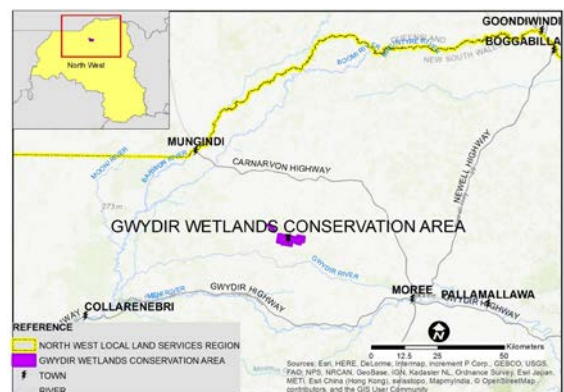
North West LLS and the University of NSW have been investigating potential application of a two stage remote sensing approach for the regular surveillance of invasive weed species across the region. This research project applied a Landsat satellite remote sensing technique at a large landscape scale to identify the potential Water Hyacinth incursion area. Then, a high resolution drone (Unmanned Aerial Vehicle) remote sensing technique was used to refine the result within the potential water hyacinth incursion area, drone sensing may not be cost effective for regular surveillance of large landscapes (NIWAC 2015).

This paper discusses conceptual frameworks and preliminary results of this research project based on its pilot application in the Gwydir wetlands conservation area.

METHOD

The North West LLS region covers an area of 82,496 km² in north-western NSW. It includes the major population centres of Tamworth, Gunnedah, Moree and Narrabri and stretches from Nundle in the south-east to Boggabilla in the north-east and Lightning Ridge and Walgett in the west (Fig. 1).

The Gwydir Wetlands State Conservation Area located in the middle-north section of North West LLS region, covers an area of 7,399 ha (www.nationalparks.nsw.gov.au). In order to cover the large area of the Gwydir wetlands, satellite remote sensing has been chosen as the main technique for Water hyacinth detection while airborne drone remote sensing was used for validation and further refining the potential Water hyacinth distribution map.



Landsat satellite image preparation:

A series of Landsat images captured from January 2015 - June 2017 have been used to identify potential Water hyacinth incursion area in the study region. First the Landsat images were downscaled from 30 m to 7.5 m pixel resolution using pan sharpening and cubic convolution techniques. Then, the images were classified using a Spectral Angle Mapper (SAM) Classification algorithm for delineating potential Water hyacinth incursion area. The SAM method classified the image to either likely water hyacinth or other vegetation area based on the sample spectral signatures.

Two sets of spectral signatures were used in this study including:

i. Field spectrometer survey: A field spectrometer survey was conducted on 19-20 May 2016. This survey collected spectral signatures of Water hyacinth and other vegetation around a known Water hyacinth incursion area in the Gwydir Wetlands (Fig. 2). Spectral signatures were measured from 350 nm to 2500 nm with an interval of 3 nm using an ASD field spectrometer.

ii. Geotagged photographs taken from a helicopter: Moree Shire Council conducted an aerial survey on 17 March 2016 for identifying Water hyacinth incursion in the Gwydir Wetlands Conservation Area. Geotagged photos acquired by the aerial survey were used to locate Water hyacinth sample pixels in the near dated Landsat image. Then the reflectance values (spectral curve) from those sample pixels were validated using field spectral data. The best fitted pixels were selected as the training data for classification of Landsat 8 images acquired on same month or closest date.

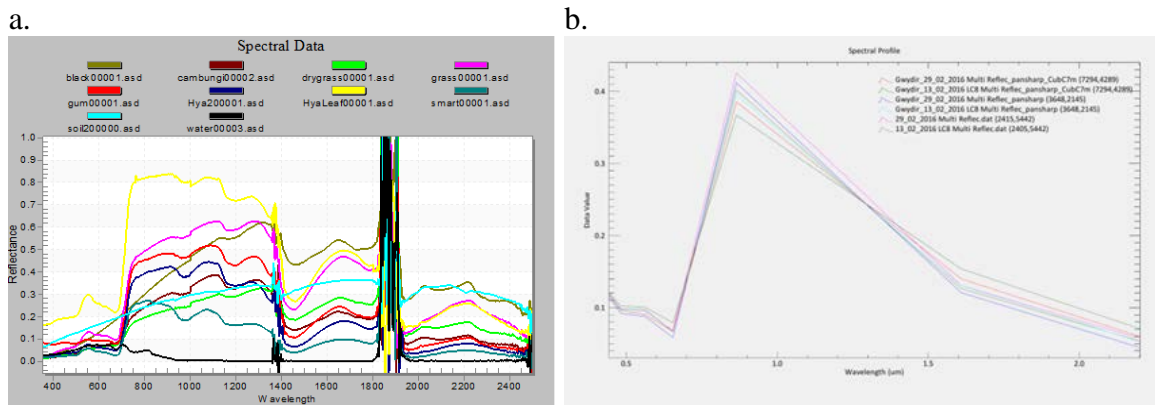


Fig 2: Example of spectral data used for image classification; a. Sample spectral signature collected from Gwydir wetlands using a field spectrometer, b. Water hyacinth sample spectral signature generated from Landsat images based on location of Geotagged photos.

Landsat image analysis for identifying potential water hyacinth incursion area:

The potential Water hyacinth incursion maps derived from the Landsat images were combined to create a frequency map of potential incursion. A higher value in the frequency map represents more likely Water hyacinth incursion area and lower value represents less likely. A drone survey was conducted to collect high-resolution images from the potential Water hyacinth incursion area identified by the Landsat image analysis. The drone images were used for validation of the highly likely Water hyacinth incursion area and refining the Water hyacinth distribution map at a local scale.

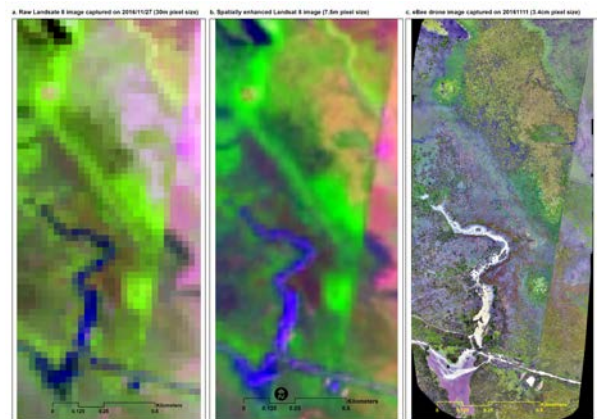


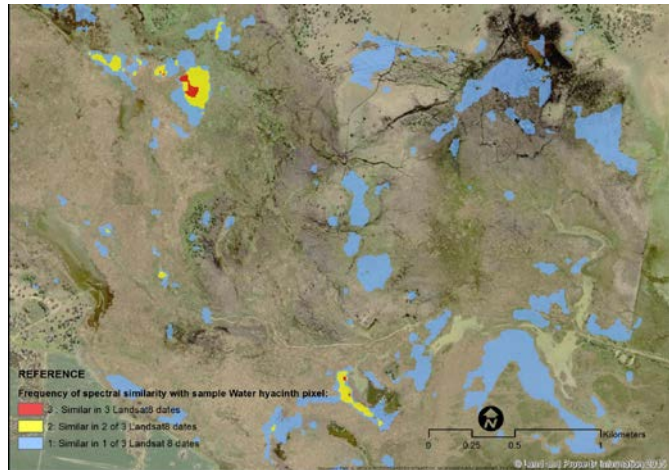
Fig 3: Example of Landsat 8 image and a Drone image of a section of the Gwydir wetlands. From left to right: a. Pseudo-natural colour view of a raw Landsat8 image (30 m pixel size); b. Spatially enhanced Landsat 8 image view (7.5 m pixel size); c. A mosaic view of 291 images captured by eBee Drone (approximately 3.3 cm pixel size).

Drone survey for further refining the results:

Following potential areas identified in the March 2016 image, a drone survey was conducted on 10-11 November 2016 at two locations in the Gwydir Wetlands for refining the results. Two types of drones were tested including a fixed-wing drone (eBee) and multi-rotor drone (Phantom).

PRELIMINARY RESULT AND DISCUSSION

Landsat 8 images have a pixel size of 30 m at visible and infrared bands and 15 m pixel size at panchromatic band. The 30 m pixel resolution Landsat images were spatially enhanced to 7.5 m using standard image enhancement techniques called Pan-sharpening and Cubic Convolution processes inbuilt in ENVI software. Figure 3 provide a comparative view of a raw and downscales Landsat image and a view of eBee image mosaic of a section of Gwydir wetlands covering an area of 1.05 km². The eBee image view created from 291 images captured at a pixel size of about 3.36 cm (Fig. 3).



In total, 43 Landsat 8 images were collected over three consecutive years 2015 -2017. This multi-temporal data offered a unique opportunity to analyse the spatial and temporal pattern of Water hyacinth growth. Fig 4 provides example of SAM classification results representing areas spectrally similar with the sample data collected by field spectrometer survey or derived from Landsat data using the location of the Geotagged photos from the helicopter survey.

CONCLUSION

Landsat 8 images can provide a cost-effective means of regular surveillance of vegetation behaviour at larger landscape scale as they are available for free for non-commercial uses and have a repeat cycle of 16 days. However, because of relatively low ground resolution compared to the patch size of priority weeds species incursion in the North West region, Landsat remote sensing can be applicable for identifying a potential incursion area at a larger landscape scale, which can serve as a basis for locating areas for detailed survey using a high-resolution remote sensing such as drone sensing or high-resolution commercial satellite or aerial missions.

ACKNOWLEDGEMENT

Landsat8 images used in this study were downloaded from the United State Geological Survey site (<https://glovis.usgs.gov/>). We are grateful to Ian Schwartz, Moree Shire Council for providing Geotagged photographs and support during the field surveys. Sincere thanks to Bronwyn Cameron and Matthew Davidson for the constructive feedback. This feasibility study was funded by the North West LLS under Catchment Action NSW and the Australian Research Council's Discovery funding scheme (project number DP130101694).

REFERENCES

- Albright, T.P., Moorhouse, T.G. and McNabb, T.J., 2004. The rise and fall of water hyacinth in Lake Victoria and the Kagera River Basin, 1989-2001. *Journal of Aquatic Plant Management*, 42(JUL.), pp.73-84.
- Everitt, J.H., Yang, C., Escobar, D.E., Webster, C.F., Lonard, R.I. and Davis, M.R., 1999. Using remote sensing and spatial information technologies to detect and map two aquatic macrophytes. *Journal of Aquatic Plant Management*, 37, pp.71-80.
- Hestir, E.L., Khanna, S., Andrew, M.E., Santos, M.J., Viers, J.H., Greenberg, J.A., Rajapakse, S.S. and Ustin, S.L., 2008. Identification of invasive vegetation using hyperspectral remote sensing in the California Delta ecosystem. *Remote Sensing of Environment*, 112(11), pp.4034-4047.
- Malik, A., 2007. Environmental challenge vis a vis opportunity: the case of water hyacinth. *Environment International*, 33(1), pp.122-138.
- NIWAC – Northern Inland Weeds Advisory Committee 2015. *Feasibility Study – NIWAC Integrated Aerial Surveillance Project 2013-2015*.
- Revenga, C. and Tyrrell, T., 2016. Major River Basins of the World. In C.M. Finlayson et al. (eds.), *The Wetland Book*, Springer Science+Business Media Dordrecht, DOI 10.1007/978-94-007-6173-5_211-3

BEGINNING A NEW ERA

Peter Russell Scott

Authorised Officer Liverpool Plains Shire Council,

60 Station Street, Quirindi, NSW 2343

Email: peter.scott@lpsc.nsw.gov.au

INTRODUCTION Most of us attending this 2017 weeds conference are off to a flying start to experience the highs of working smarter together. We are now equipped with new found knowledge to strategically go forward to oversee and administer Weed Control under the new Biosecurity Act 2015.

- At the 1999 Weeds Conference in Ballina, Weeds Officers were enthusiastically informed that our status and capacity would holistically be elevated through a new ambitious undertaking with a strategically developed direction. A specifically targeted vocational training scope evolved progressively, and was provided to equip us as educators to pass on cutting edge skills and strategic integrated weed control information. We have arrived and now it all starts again.

BACKGROUND

Legislation

Previously Weeds Officers were referred to (among other things) as “only Burr Cutters.” Many have progressed to complete, or were encouraged to continue and accumulate, recognised tertiary education competency units, on the way to achieving relevant Management Diploma qualifications. Amongst us too are an illustrious few either working toward, or have achieved, relevant Degree qualifications, to be well equipped and positioned more sophisticatedly to take us forward.

All this partnered with productive technology output, supports the compounding and promotion of our industry’s purpose. This has been confirmed in subsequent NSW Weed Management review assessments. Some of these have resulted in perceived beneficial consequences.

Significantly, tenure neutral obligations are a long overdue objective. Now they are a reality, having been identified in the past as lacking and were acknowledged as a barrier for some stakeholders not to accept or fulfill their obligations. It must now be embraced at all levels. However a note of caution, any modification of the accepted tenure neutral approach, a shared responsibility, with expectations of an evidence based outcome, will effectively facilitate the continued avoidance of accountability. A quick look would confirm a hypocritical compromise of intent and a violation of the objectives of the Act.

New Technologies

Combined elements of control activity and herbicide efficacy have elevated Integrated Weed Management outcomes, while remote controlled retractable spray units are now an everyday expectation.

Emerging from early experimentation, both aerial and on ground, are unmanned, electronically censored units with automated identification capabilities through algorithms, to identify weeds within multiple plant species, on the run. This has been integrated into boom spray configurations capable of delivering multiple options of selective or broad spectrum herbicide application to a specific target from retrievable spatial data captured as live mapping outcomes. Weed spraying applications, specific crop yield data analysis and outcomes populated during harvest are then utilised efficiently to deliver prescriptive fertiliser applications in subsequent seasons.

- Consider the potential of the same detection capability, but replacing herbicide knock down capacity with electronic (microwave) technology, coming to zap weeds only.
- Advanced satellite imagery is increasingly being incorporated into many planning applications as are drones and their flexibility for observations.
- The concept and capacity of strategic rapid responses capabilities mobilized initially is a proven effective management tool, utilised with wide ranging benefits.

Comments About Legislative Changes

The challenge now is to nominate and measure evidenced based outcomes that the description, “Priority Weed” provides over Noxious Weeds? None have been offered for objective comparative analysis!

The legislated generic description, “Priority Weed,” to replace “Noxious” has no credibility and was made without a transparent mandate. It cannot be justified as an effective “beneficial adjustment to the overall weeds management framework.” It’s an insipid, ineffective attempt to rebrand a definitive, unambiguous article. It can neither be quantified nor qualified and provides no positive likelihood of any additional beneficial weed control outcomes. The narrative does not articulate or convey authority that will alert hesitant landowners or highlight the status of the worst of our worst weeds. Maybe it should! But in reality it doesn’t. If others had evaluated the intention sooner, maybe it wouldn’t still be a question. However, there are many issues and actions that do need to be prioritised. Some are mentioned in the statewide regional strategic weed management plans (RSWMP) and elsewhere.

To alleviate and demystify concerns about the lack of genuine efforts to control weeds, more weeds must be included, not fewer, and all with explicit, supported mandatory compliance expectations. Many omissions are irresponsible when objectively measured against compounded, long term risks and impacts. It further exposes and highlights the lack of genuine support for effective weed control.

Yes it's agreed, all weeds do represent a biosecurity risk but here's the rub. Despite the comprehensively categorised lists of weeds to choose from, surprisingly, relatively only a few have been endorsed as Priority Weeds, through the WRA process. The lists include, but are not limited to, Noxious Weeds, Crop and Pasture weeds, Invasive or feral native scrub, Weeds of National Significance (WoNS) environmental weeds, Environmental Alert List, those acknowledged as, A Key Threatening Process, aquatic weeds, conflict species, genetically modified (GM) or herbicide resistant and even those as a food, fiber or a medicinal material source. The calculated and measured outcome intentionally moderates the financial (\$) impact overall, on Tenure Natural obligations.

The relatively few weeds selected for attention and targeted for obligated control measures, understates the real problem. By labeling them: Not a "Priority or Noxious weed" sets them aside to be overlooked. This is why there are so many widespread weeds now, and more will spread, widely and unchecked, continuing to grow.

The net outcome of this process highlights our industry's "elephant in the room." We can be in awe of the edifice but the major component is out of sight and at our own peril, conveniently ignored. There is significant historical precedent for pests, and weeds too, like mimosa, honey locust, deer, English and Indian myna birds to mention a few. Unchecked, significant risk of impact compounds for many weeds over the longer term, and this is grossly under estimated. Not being classified with mandatory landowner control obligations is a flawed justification for them to be overlooked by unaware operators.

Any local control authority (LCA) or an individual pursuing effective control of a weed not listed as a priority will need to consider risks and options, but first they need deep pockets with \$'s to burn, just for the legal battle. Who will test this unreasonable and untenable situation?

Emphatically, without timely, effective, ongoing control work, all weeds continue to grow and propagate. So then ask, "Who pays for that?" The answer is that: It's not just the immediate offender, a current here and now Land Owner in isolation". The long term legacy of impacts and negative consequences compound, while growing environmental costs mount up unreasonably for future generations to deal with. So, with hindsight and because time exposes inaction, just look back at the ones (weeds) that did get away!

Many former successful projects continue as ongoing works in progress and as established, educational observation sights in the real space of working commercial operations. Clearly, these demonstrate a practical working example for landowners to follow. The intent, supported by effective on ground activities, delivers beneficial outcomes. These include, but are not just restricted too: St Johns wort, blackberry, black locust, riparian rehabilitation and more recently, positive control trial results for Espartillo have emerged. Knowing that all these were difficult targets, now it's with good reason, there must only be a few acceptable circumstances where ineffective outcomes are vindicated. Many of us know of similar situations. So going forward, all new policy expectations must now reasonably demonstrate and effectively be outcome based.

Failed, or ineffective control outcomes, must now only relate to those weeds in situations known to have no reasonable practical means of control. Fortunately, this is limited to a small number. So without fail, this situation and the status of those few weeds must ring alarm bells. These are the **priority weeds** that must be the focus of research. All options must be examined to discover and exploit their vulnerabilities rationally, to find reasonable means of control: Chemical rates, timing of applications or physically integrating systems with intervention during seasonal growth stages from germination and pre-emergence. Consider for example, those lingering in the “too hard” basket, such as Lippia, Espartillo, serrated tussock, fireweed, coolatai grass, Chilean needle grass and lovegrass, plus prevalent and emerging herbicide resistant species too.

Ultimately, it is how a problem is actually dealt with that determines the control efficacy (outcome) of the activity, utilised to fulfill a general biosecurity duty (*GBD*), ensuring *as far as is reasonably practicable, that biosecurity breaches* (far reaching negative impacts and consequences) *are prevented, eliminated or minimised*. AND – It can be done in more situations than it currently is. So, as an industry and as Authorised Officers, we must be allowed and supported to expect that it is.

Tenure Neutral: Remember too, without fear or favor, irrespective of entity, that Crown or Public Land is dependent on the federal funding \$ for funds to monitor, manage, maintain and develop it for mutual benefit. Traditionally, (aside from the perennial, “No Funds available”) they have harbored and hosted outcomes that inflicted pests, invasive weeds or vermin onto the wider community, negating neighbors’ efforts unreasonably, at unacceptable costs.

Diligent landowners routinely undertake follow up maintenance that is intuitively, cultivated as good management for long term beneficial outcomes too. Some old wisdom says, “A farm’s best fertiliser is in the footsteps of its owner.” That’s apparent when boundary riders routinely inspected fences and monitored watering facilities too, while actively looking to minimise and manage problems through early detection. The iconic Dingo Fence was once an effective strategic containment and exclusion tool, until its demise through lack of maintenance. But revitalised as a priority, they are again, providing effective protection. Consider the potential of drone operators as modern-day boundary riders!

Any obvious lack of weed control always compounds the mire of neighborhood disputes and perception aggravates discontent. Noncompliance leads to protracted, unproductive, emotive (legal) battles, without a positive resolution. It embroils the more diligent neighbors against those cash strapped, uninformed, lethargic or indifferent and absentee owners of disputed or abandoned blocks. Some even “choose” to be oblivious to the fact that land ownership, is a privilege. Clearly, these all come with obligations and responsibilities too, that must be considered in the bigger picture, outside any individual’s own situation.

- No landowner /operator has an intrinsic right to inflict a biosecurity risk or impact from pests, weeds, vermin or pollutant contamination onto a neighbor, a

community's economy or their amenity. Ignorance or malice cannot be excused, as most should reasonably know.

- The Community Based Social Marketing (CBSM) tactic with its best intended logic is a soft first option that has always been available and is used initially as subtle coercion but there are no supported evidence based outcomes that herald its infinite success. Ten percent of our clients are a significant distraction and occupy up to 90% of our time to the detriment of our priority, core business. So if this approach is not initially taken on board, working a wider general strategic application realistically has limited application. Many just argue to shirk their responsibilities, despite being aware of their obligations and the compelling logic of current scientific options. Emphatically, they should reasonably know but just say “Narrh, I am not going to do that and you can't make me!” Without supported tangible reasoning, this open-ended fallback position (escape) is not acceptable and must not be endless or tolerated. A base line standard that underwrites an outcome of current Best Management Practice (BMP) is a legitimate expectation. Ultimately this will foster productive output, benefit the community's economy and not compromise biosecurity, while being aesthetically gratifying too. A very good all-round and obviously positive, evidenced based outcome!

Regrettable Highlights

Some evidence based procedural shortcomings were recognised, acknowledged and highlighted for supported remediation in the last NSW Weeds review. Regrettably, not all have been embraced. Instead, we've been distracted and misdirected down the garden path to pursue the aberration of priority weeds. A shambolic list resulted and that was signed off by an agreeable committee in denial. No substantial or beneficial legacy is on offer, only further limitations and barriers. Underlying obligations cannot be enforced, having again been deliberately framed in loose ambiguous language that will facilitate continued evasion of responsibilities.

Supported Recommendation: 2 c. (1) articulates: - “transparently evaluating weed declarations, based on assessment of potential long term risks and impacts to the economy, environment and community.” The outcome falls short of being transparent.

Supported Recommendation: 3 c. “provide a legislative basis for tasking regional weed committees with developing regional plans and priorities for wide spread weeds and surveillance. These plans will be unambiguous, enforceable, tenure-blind and inclusive of all relevant stakeholders.” Like the potentially expansive plans, delivery falls short.

Unsubstantiated claims around the “general failure” and “ineffective outcomes” of previously legislated weed declarations were offered as leverage for change and published as a distraction. However, two facts are relevant and repeated. They expose and dispel the claims. Firstly, an external, influential and dominant reluctance remains with a conspicuous absence of rigor and robust support, from both state and local government authorities. The intent “to get serious about weeds” and see the job through and the “NSW - no space for weeds” mantra also lacked the deserved support it should have received. By

failing to provide compelling incentives for compliance, the void remains. Secondly, for many plants and pest species too, the time frame from discovery to declaration to effective action, has been highlighted by procrastination and delays. For example, honey locust, mimosa, deer, Indian and English myna birds, and more. Future objective projections and transparent, Biosecurity Risk Assessment undertakings must be accelerated and delays for legitimate intervention minimised.

So much for the “Supported Recommendation” for stronger enforceable obligations: Follow the Progress [Draft Version 0.5] NW RSWMP “*Neither the LLS Act 2013 or the Biosecurity Act 2015 have provisions for making a statutory plan which can be enforced. This plan is not therefore, a regulatory (enforceable) document but sits (without valid influence) as a sub-plan of the LLS Strategic Plan.*” It says more: “*While this plan is not enforceable in its own right, it does (only) provide “evidence” of the community’s will, in this matter: - and it says more but!*”

Don’t be misled, or jump to conclusions. All is (not) well, again follow the progress! [The Draft 0.5 Version] was replaced across the state, without further consultation. An executive decision to appease, with political correctness and soothing lingo! You be the judge, or do we need a Legal Precedent?) Now, *23rd May 2017 - Page 22, the final and completed - LLS NW RSWMP 2017-2022 - “Agreed standards for weed management”*

In terms of regulation, the RSWMP plays an important role in articulating the shared responsibility principle of the Biosecurity Act 2015 (the Act) and communicating (only and without any supported actions) weed control obligations. Although the Plan is not a regulatory document in the traditional sense, it provides information to enable people to effectively discharge their (muted) obligations under the Act, including their GBD.

The GBD requires that all land managers and users ensure, as far as is reasonably practicable, that biosecurity breach is prevented, eliminated or minimised. It does not prescribe how the outcomes are (to be) achieved. For this reason, the plan does not include prescriptive (or Mandatory) measures for landholders and users to discharge their general biosecurity duty. The plan focuses on the outcomes to be achieved, (e.g. through Community Based Social Marketing) allowing for different measures to achieve the same outcome.

While not technically a Regulation, the plan links the key elements of Knowledge, Risk, Practicability and Outcomes for discharging the GBD.

After much procedural blustering, that the cultivated change was progress, the opposite revelation has emerged. The “proposed, strong enforcement tools, including significant penalty provisions.” remain unsupported, amidst continued denial, through avoidance of reality. It’s a Status Quo!

- With the wisdom of hindsight and when the shortcomings are realised, the Minister responsible will not be pleased nor will the community. Many issues have again been avoided or understated and many problems have not been resolved.

- How a problem is dealt with determines the efficacy of the outcome.
- Evaluating weed control's evidence based outcomes necessitates scrutinising management. Success or failure exposes compliance or alternatively, noncompliance!

DISCLAIMER: The opinions and delivered interpretations are deliberately intended to be a compilation of the writer /presenter's alone. In no way do they reflect ideals or an opinion of any other individual or organisation. Any similarity assumed is randomly coincidental. They are not claimed to be unique, or considered as original, or intended to encroach.

REGIONAL JOINT PROJECT COLLABORATION

Mel Wilkerson

Snowy Valleys Council 76 Capper Street Tumut, NSW 2720

Email: ranger@snowyvalleys.nsw.gov.au

SUMMARY The purpose of this paper is to highlight and show the potential benefits of Collaborative project works between organisations and jurisdictional boundaries. In order to examine this more closely two specific projects were identified as part of a greater whole within a regional context. The organisations spanned across separate state organisations such as Forests NSW and local Councils, to nationally controlled groups with state direction such as National Parks and Wildlife and Crown Lands. It also brought into the management and decision cycle for weed control projects independent large scale private industry such as HUME Forests and others.

The idea was not new, but took a newer approach to cajoling cooperation amongst the participating organisations.

The Pros:

1. Coordinated works completed across jurisdictional boundaries.
2. Specific agreed projects with targeted and measurable outcomes
3. Elimination of “Lazy Neighbour Complaints”
4. Greater outcomes with no overlapping works
5. Coordination of project works logically sequenced
6. Less individual cost and resource allocation to each participating organisation to achieve the same outcome
7. Collaborative Joint Funding applications receive greater response and success than individually managed localised projects.

The Cons:

1. Change of mindset and ability to let go of “control” to project manager (within reason)
2. Stovepipe mindset of higher management
3. Coordination and management is still personality driven and not entrenched as a process
4. The logic of paying contractors to do work coordinated and managed by another organisation in another land jurisdiction is not fully understood by many upper level managers or decision makers.

BACKGROUND

Regional Blackberry Forum

The regional Blackberry forum was a re-constituting of an older initiative from the 1990s. An attempt was made then to try and bring regional bodies and organisations together to facilitate cooperation and mutual support in weed control programs.

Unfortunately, due to organisational stove-piping, state micromanagement, inconsistent and ineffective reporting, little or no accountability and other issues, the initiative essentially died on the birthing table. The entire concept of regional cooperation and joint project management was personality driven by weeds officers. Unfortunately this approach was not generally supported by organisational management viewing their own little piece of the turf as sacrosanct and stand-alone.

In 2014, Tumut Shire Council was tasked to complete a “complete regional study” to deal with the major issue of blackberry infestations throughout the Shire and the regional area. Once completed, and with a little arm twisting, it was decided to re-establish the regional blackberry forum that failed in the 1990s.

There were however; two big differences however in the approach taken:

1. The forum concept was addressed to Chief Executive Officers, State government bodies at the general manager and CEO levels, as well as independent organisational bosses such as National Parks and Wildlife, Forests NSW, Department of Lands, Minister for Primary Industries and so forth. The big difference was the inclusion of private forestry industry. These invitations were done simultaneously so each knew the other had been asked to participate. The goal was to add pressure to the bodies to participate at the top level because their biggest complaint was “the other guy not doing their stuff”.
2. The second was an informal Memorandum of Understanding with a five year commitment to the project of: Controlling, reduction and containment of blackberries within the regional area, establishing specific joint organisational projects, and overall weed reduction and rehabilitation across jurisdictional boundaries.

Prior to the forum meeting, a review of funding strategies from the various state government funding providers was done and a subtle but significant change in process was noted.

2014-15 was considered the banner year for change in both accountability and reporting requirements as well as the approach to state government funding. Although on the surface neutral and objective, the application criteria across the funding providers had a greater push for “Joint Organisation Collaborative Projects” and they were more than willing to throw money to those types of projects in apparent preference to others. In short, the more people involved, the more boundaries crossed, the better it looked on paper.

The downside of this was that funding still had to be managed by one group and projects managed by a single point of contact for overall control. In other words, applications were essentially personality driven by anyone willing to pick up the reins and run the obstacle course of state government grant requirements.

The forum met, chaired by an independent weeds professional from outside of the regional area, (Rob Ferguson). After the standard introductions and mutual complaints, it was decided to define 5 specific projects for mutual cooperation and each would be managed by a specific person in an organisation.

Three of the projects were under the management auspices of Tumut Shire Council, and directly managed by Council as the project manager. These included,

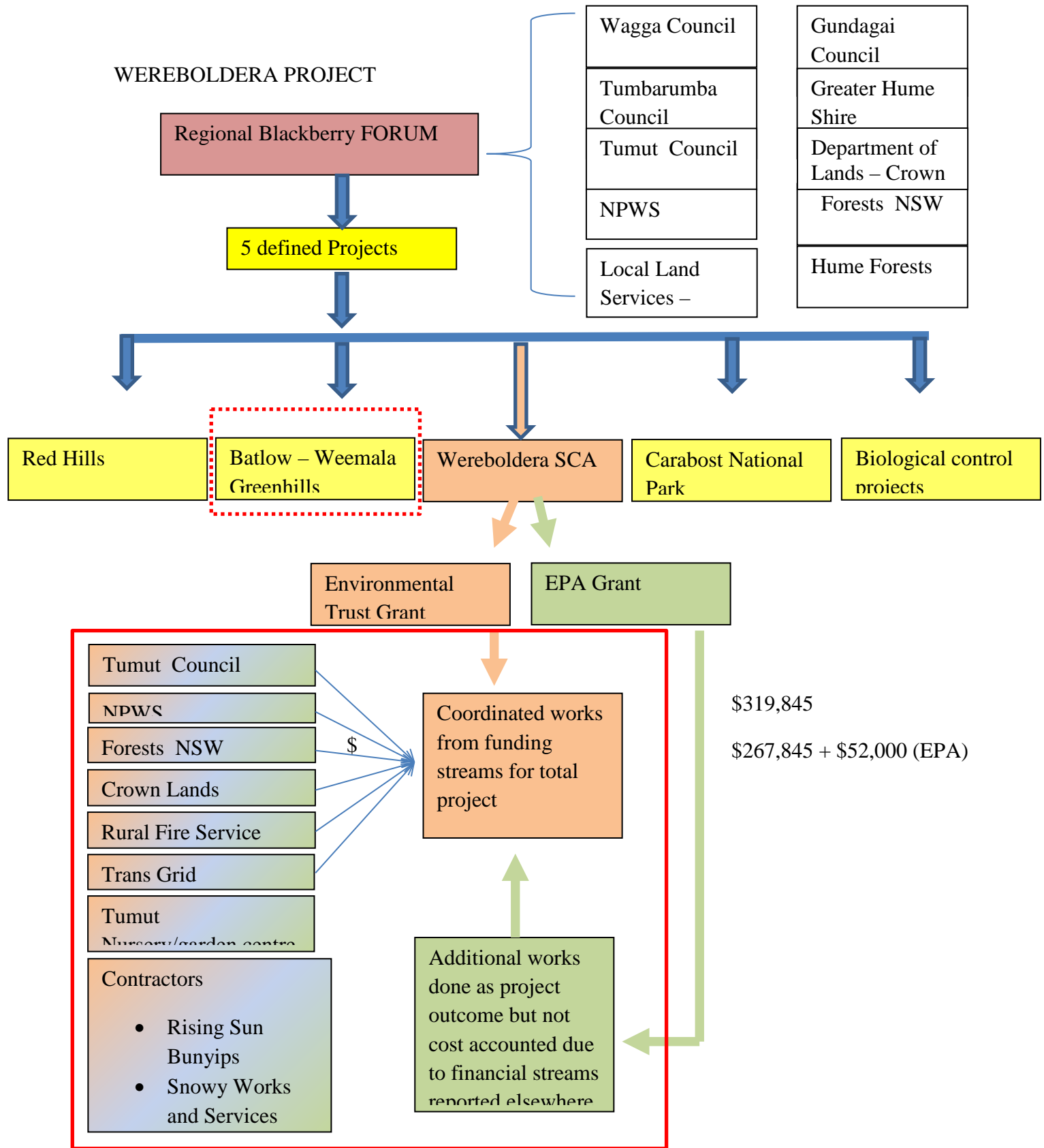
1. Wereboldera / Tumut Common – rehabilitation project
2. Reedy Creek / Weemala / Greenhills (Batlow) project
3. Biological Control nursery project for Blackberry, St John's Wort, Bridal Creeper, Scotch Broom and Patterson's Curse. (joint managed with Tumbarumba)

The other two projects were:

4. Carabost National Park – Post fire weed control and rehabilitation project – (Greater Hume)
5. Red Hills Blackberry control and rehabilitation – (Forests NSW)

The following diagrams briefly outline two of the project works from forum decisions.

WEREBOLDERA PROJECT



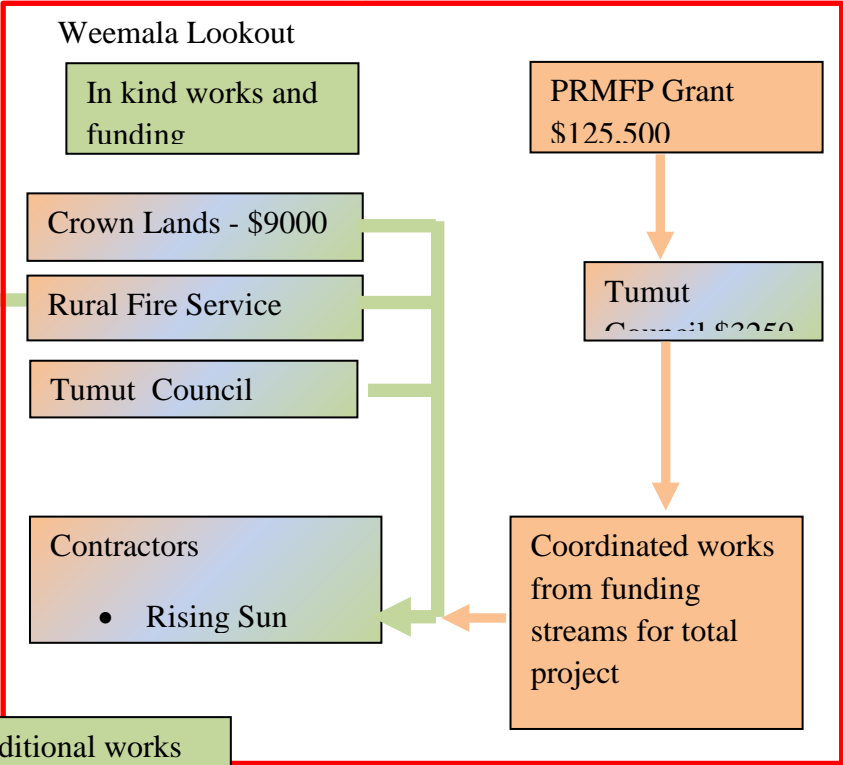
5 defined Projects

WEEMALA LOOKOUT / BATLOW / GREENHILLS PROJECT

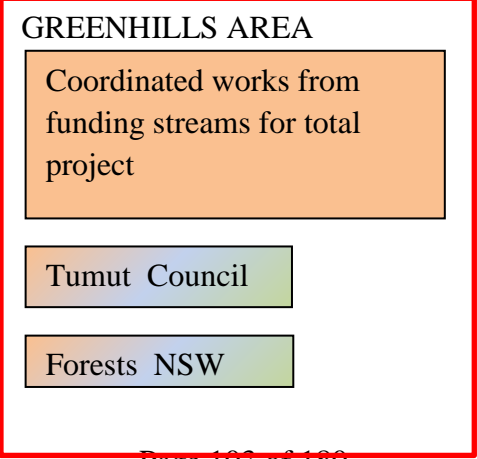
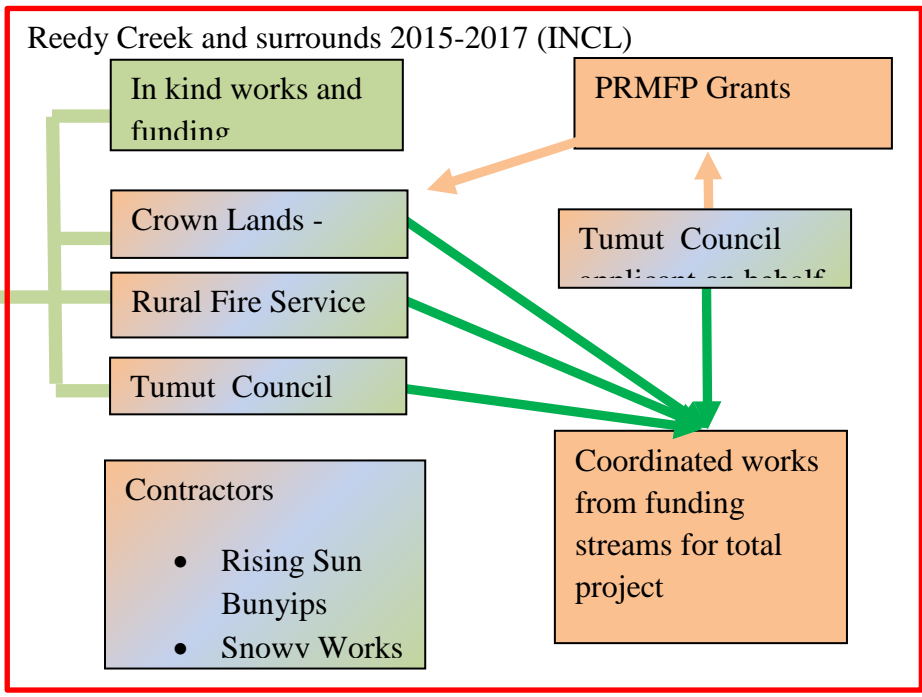


- Red Hills
- Batlow – Weemala Greenhills
- Wereboldera SCA
- Carabost National Park
- Biological control projects

3 sub Projects – Reedy Creek and surrounds. Weemala Lookout



Additional works done as project outcome but not cost accounted due to financial streams reported elsewhere



As part of the forum agreement, each defined project was under a single management authority and each affected agency (stakeholder) agreed to support the project goals. The biggest hurdle was the seceding the commitment and allocation of resources normally concentrated on a small portion of a bigger picture to be effectively working for someone else, and sometimes on someone else's property. Nevertheless, once the potential cost savings and outcomes impact were explained, all parties agreed to "give it a go" for the three to five year timelines on each project.

In addition, all stakeholders agreed to seek out and apply for external funding (grants etc.) from sources that would be mutually beneficial to each project area. This included complimentary supporting projects for example, EPA grants to combat illegal dumping.

In each case, as noted in the diagrams above, the projects were coordinated by a single agency or person with the cooperation and participation of the project partners. Each project partner contributed works as an in-kind contribution towards their own internal target goals, but by working collaboratively within the project and allowing works to be managed and coordinated by a single source, greater impact, benefit and outcome was achieved at a significantly reduced cost than piece-mealing individual portions.

The project manager was able to coordinate works across jurisdictional boundaries and achieve target goals requiring far less asset contribution, contractor cost or individual purchase of consumables such as chemical herbicides. Utilising a single or in some cases minimal contractors to do the entirety of the works across different funding streams also made for greater contractor enthusiasm (a larger overall pay check) and a sense of project ownership for the contractor. This too resulted in a better work output with no overlap.

To further illustrate the benefits of collaborative project management I will breakdown one of the above projects. The one chosen is the Wereboldera Tumut Common Area as it was a single project with funding and work streams from a myriad of sources.

1. TUMUT COMMON / WEREBOOLDERA SCA – REHABILITATION AND RECOVERY PROJECT

The project began in September 2014. It was one of several listed projects in a larger regional weed management project in the Riverina/Murray/Southwest Slopes area. This specific area is also encompassed within a separate but in conjunction with an EPA project. Some works were mutually compatible and combined for maximum results output to both projects.

Focus

This project was primarily focused on Weed removal and rehabilitation, both natural and assisted to the Tumut Common / Wereboldera State Conservation Area (SCA).

Description

The area referred to as the Tumut Common is located just west of Tumut adjacent to the township. It is comprised of 273.6 hectares of primarily vacant land with individual portions managed by Tumut Council, Forests NSW, National Parks and Wildlife and the Department of Lands.

The project will enhance the aesthetic value of the land; promote better access to natural bush land recreation areas; enhance and speed the recovery, regrowth and rehabilitation of native species in a degraded EEC; and provide substantial asset protection to the SCA currently under threat from invasive species. Tumut Council will coordinate all project works. The project area, is currently degraded and for the most part an inaccessible former white box yellow box grassy woodland once used extensively by bush walkers and birdwatchers. It has become the site of major non-native and noxious weed infestations in particular, blackberry, invasive wort, privet and cottoneaster as well as more recently bridal creeper as a result of illegal greenwaste dumping.

OBJECTIVE

The project is required to restore native bushland and wildlife habitat and to re-establish the protective buffer between Tumut and the Werboldera State Conservation (SCA) which hosts a unique collection of flora and fauna and is the only place in NSW with a known well established Norton's Box - Red Stringybark grass-forb mid-high open forest. This SCA is under direct threat from the growing expansion of non-native species, particularly bridal creeper. A successful project will reconstitute the bushland and remove the threat to the SCA.

Collaboration

This is a joint submission on behalf of the four stakeholders to:

1. Control the invasive spread of non native woody weeds, and
2. Treat, remove and prevent spread of bridal creeper, mitigating the threat to the SCA.

The two year plan will see treatment of all blackberry and non native weeds, (integrated chemical and manual strategy) and a concentrated effort to remove the bridal creeper, the greatest threat to a unique conservation area habitat. A successful project will show little or no remaining blackberry and other woody weeds and the bridal creeper will have been effectively treated and manually removed

The Tumut Common, although a degraded EEC land area, remains a popular local recreation area. It has no specific status as far as core business responsibilities for management. Council, Forests, Parks and the Department of Lands however recognise the land location and status, and contribute what resources are available to contain the invasive weed problem to protect more sensitive lands such as the SCA, parks and forest trails. Work in the Common has been conducted under the auspices of Tumut Shire however, little has been achieved other than moderate containment at this point. Although limited weed containment works have been moderately successful with blackberry and St. John's

wort, bridal creeper control has not achieved the same result and the spread although slowed by control efforts, continues

Project Significance

The Common is an established but degraded Blakely's Red Gum, Yellow Box, White Box tall grassy woodland currently stress from invasive weed expansion, in particular, the invasive spread of Bridal Creeper from Green-waste Dumping. The Common remains a very popular bush walking recreation area and is the prime access to the Werboldera SCA. Use however is severely restricted due to poor and inconsistent management. The Common is also a buffer protection zone to the existent SCA which is an Upper Riverina Dry Sclerophyll Forests (OEH Descriptor Class U66) Norton's Box - Red Stringybark grass-forb mid-high open forest. The SCA is under direct threat from the growing expansion of non-native species, particularly bridal creeper. Werboldera SCA hosts a unique collection of flora and fauna and is the only place in NSW with an established large U66 community

A 2014 Regional Weeds Memorandum of Understanding between Tumut and other regional Shire Councils, National Parks, Department of Lands, Forests NSW, and Local Land Services (LLS) and others, identified this area as one of five high value projects areas for ongoing longer term management and control works to include primarily blackberry but other weeds due to its asset protection value. Actively seeking grant funding is part of the working group's mandate. Tumut Shire Council is the lead agency for this specific project

Collaboration Does Work – It was not just another funding hurdle.

Joint projects with a single project manager/facilitator work really well. They are able to achieve maximum benefit with the least amount of effort and costs. By controlling and directing specific works in a coordinated manner, less time and effort is spent on duplicating manpower through agencies, administration and supervisory monitoring costs and significantly reduced, and all agencies can achieve maximum success with the minimum of financial input.

One key benefit that was unexpected was that each agency would bring their “bosses” on tour to show the work being done on “their area” in conjunction with other organisations working together. This appeared to be a big selling point to the higher management who ran with the banner. It was particularly well received that their specific commitment was less costly, less resource intensive, and under the MOU, easy to manage because all they had to do was pay the agreed invoice for their area. Someone else did all the hard work, and they got all the credit for having a particularly troublesome area dealt with. This was a big tick of the list of chores.

A short calculation of this project shows that if these works were done individually with each organisation focused on their own little piece of the patch, the overall cost in manpower, plant, multiple team coordination and management would have more than

tripled the cost of the overall expenditure to each group. Further, as had been done in the past, only token work was done in the area, mainly to maintain access trails for works crews. The reason was the cost of cleaning up “their area” when the others don’t clean up the surrounding areas. It was generally viewed as a waste of time because it would have no long term benefit.

Cost To Outcome Benefit Comparison

Looking at a few benefit examples in relation to this project however, the fundamental concept applies to all. Coordinated management and collaboration results in:

1. More focused and specifically targeted on ground works
2. Mutually beneficial and supporting outcomes across land tenures
3. Less overall cost and commitment from each participating stakeholder
4. Lower demand on resources for greater outcomes
5. Lower long term maintenance costs

Better Bang For The Buck

A few examples of the benefits achieved by individual project partners are:

TRANSGRID: \$223,000 saved – objective achieved. Transgrid owns a main powerline that runs 2.5 km through the top of the project area. It is extremely difficult terrain with steep up and down tracks on substantial uneven solid rock base terrain with shallow cover. To re-establish the trails and tracks for powerline access and maintenance, the Transgrid surveyor requested Council to assist in order to get access. In short, Council Officers knew the terrain and the surveyor did not. He had estimated a need of \$273,000 to re-make the tracks along the powerline and also it would be very costly to maintain.

The Rural Fire Service, National Parks and Wildlife, Forests NSW and organised a meeting with Transgrid on site. The fire trails and communication access tracks in the eastern portion of the area had just been done two years prior and by using them as access, an arrangement for shared maintenance of the trails was made. Transgrid was able to access the lower base lines and hilltops of their works with support vehicles and by sharing access maintenance, only a few tracks had to be expanded in the area. Transgrid was very appreciative of this infrastructure benefit, and committed \$50,000 to their line access, \$47,010 of which was directly beneficial to project works not directly related to the powerline. In addition they revegetated significant areas and closed off a few tracks. The result to Transgrid was a documented saving of \$223,000, a lower ongoing maintenance cost for access tracks. The benefit for the project was an in-kind contribution of \$47,010 in works that did not have to come out of the project budget.

National Parks and Wildlife: \$170,360 saved – outcome achieved. NPWS needed to re-develop the Asset Protection Zone (APZ) for the Werboldera SCA specifically above the Tumut Common. The cost estimate alone for the NPWS area just to deal with the blackberry was \$78,000. In addition there was significant waste through the area having been illegally dumped.

In conjunction with NPWS, Tumut Shire, Department of Lands and Forests NSW applied for an Environmental Protection Agency grant to “Combat illegal dumping and clean up the area”. This grant was approved and \$100,000 was received which included garbage pick-up, as well as restoration and rehabilitation works. A substantial portion of the funding was used in the Common/Wereboldera SCA Project area. The actual cost in manpower, contractor work was \$29,640 which represented a saving of \$48,300. More significantly, by the project mutually supporting each other, nearly \$200,000 of work was achieved.

Snowy Valleys Council (Tumut Shire): \$85,300 saved – Objective achieved. Council managed a relatively small portion of this land in conjunction with Crown Lands. This part was significantly overgrown and was a frequent site of illegal dumping. Heavy blackberry infestations made the bush nearly inaccessible. Privet, wild fruit trees, African boxthorn and other invasive trees were becoming dominant in large patches. Further, large outbreaks of bridal creeper were starting to denude trees and take over the understory. This represented a significant threat to the Wereboldera SCA if left unchecked. Council had essentially no funding for weed control allocated to this area, there was no clean-up money for illegal dumping and no real long term strategy for the location. It was estimated that nearly \$102,000 would be needed to do weed control, and clean up in just the area managed by Council and Crown lands. Council committed \$16,700 over the life of the project which represented a saving of \$85,300.

Rural Fire Service: Within this project the participation and benefit of bringing the Rural Fire Service as a participating partner must be acknowledge. The RFS conducted numerous control and mitigation burns. In addition, five regional RFS areas all came to Tumut to conduct bushfire management training. Apparently a degraded bushland covered with dead blackberry, massive weedy undergrowth, piles of invasive trees having been cut down and herbicide painted, and dead bridal creeper everywhere made for a practical and containable series of controlled bushfire management training exercises. Further, chainsaw and fire trail maintenance certifications were needed and strangely enough, this same area presented an excellent controlled environment to achieve those certifications with minimal cost. The end result was that manual clearing, stacking, mitigation and APZ development and controlled burning was done through most of the area to remove the blackberry, invasive woody weeds and trees, bridal creeper etc. which in turn promoted a strong (and unexpected) regrowth of native vegetation (assisted and natural) and in the last several months a return of native flora and fauna which has not been seen in the area for many years. The cost contribution to this project borne by the RFS as a training benefit was \$43,700

Getting the Funding: As noted by the savings achieved, had each organisation decided to conduct the necessary works on their own piece of the pie (the project area) the result would have likely been what had been happening for the last 20 years - a token effort with expenditures of around \$1,000 to \$2,000 and no significant outcome or progress. The costs were just too daunting, and it was of no value if the “neighbours didn’t do their job

too”. It was easier to complain as an excuse to do token works only – this was the status quo.

Council decided as part of the Blackberry Forum to pursue grant funding. However; rather than each stakeholder pursue independent grant funding for their own areas, a joint submission was made. It is important to note that the joint submission was for weed control works over two years and had no commitment of matching funds or contributions from participating stakeholders when submitted. However, each group was committed to providing support to the overall project area as long as it was within their individual funding means. (i.e. No big shock expenses that weren't accounted for in the budget)

The Tumut Common/Wereboldera SCA grant submission was approved and \$83,500 in grant funding was received. Simultaneously a large proportional amount of a \$100,000 EPA grant for illegal rubbish dumping and clean up was received. (The EPA grant was financially administered by NPWS but works controlled through Council as part of the blackberry forum project with Mel Wilkerson as project manager).

Arrangements with NPWS, Forestry NSW, Crown Lands, TRANSGRID, Snowy Valleys Council and the RFS all saw benefits in recovering this area as part of a much bigger picture than weed control benefits. For that reason, coupled by one person managing and directing the overall works to get the best “bang for the buck”, this project was successful as it was obtaining so much additional financial support to achieve the goals in such a short time.

By bringing in all the stakeholders to work together and mutually support this project the outcomes were achieved.

PROJECT OUTCOMES

- Over 57 cubic metres of bridal creeper and Root were manually removed and the infestation areas treated.
- 4 ha of African boxthorn infestation have removed.
- Several hundreds of tonnes of other invasive species such as privet and wild fruit trees have been removed and the area to be re-vegetated.
- All 273 ha of the project area and an additional surrounds of nearly 150 ha of heavy blackberry and other infestations have been chemically treated, and mechanically removed and/or burned in situ.
- Controlled burning of dead biomass has been conducted through the area which has promoted phenomenal natural re-growth
- Two large infestations of Chilean needle grass were treated and are now under a control and monitoring plan.
- Trail access and rehabilitation works have been completed through the project area.
- Over 300 cubic metres of putrescible waste 600 cubic metres of recyclable material and about 100 tonnes of steel waste was collected an removed

- An additional \$186,344 was raised to contribute to the project in works and in-kind funding from project partners.

The project was extended (with permission) to 28 Feb 2017 to allow a final follow up and treatment of blackberry and final clean up. This was a joint project managed and administered by Tumut Shire (Now Snowy Valleys) but incorporated contributions and works from National Parks and wildlife, Forests NSW, the EPA, RFS, Crown lands, and Transgrid. This project is assessed as far exceeded its projected target goals and is now complete.

Financial Savings

- Combined Costs projections if stakeholders Crown lands, NPWS Forest NSW and Council if done independently with no funding – **\$718,700**
- Total project costs by combined works and collaboration – **\$267,845**
- Total Grant Funding received (\$83,500 PRMFP + \$52,000 EPA) – **\$135,500**
- Total cost borne by stakeholder **\$132,345**
 - RFS - \$43,700
 - Transgrid – **\$47,010**
 - Crown lands, Council, NPWS and Forests NSW - **\$41,635**

By collaboration and bringing in stakeholders, the actual cost to the four land holders was reduced by \$677,065. Thanks to state funding (grants) contributing partners the overall project saving was \$450,855.

Total Outlook - better outcome for 37.26% of the cost. Funding across all bodies

From a Land owners organisational and budget perspective this simply translates to 5.79% of total project cost to the entire project paid by stakeholders. It is easier to understand from a management and decision maker point of view then expressed that 94% of the cost will be borne by someone else and the work will be done in your area at about 5% of the cost.

\$41,635 SPENT TO ACHIEVE \$718,700 WORTH OF WORK.

- A better outcome overall
- Able to work within budget constraints and still contribute
- No complaints about neighbours = no excuses
- Less money from individual stakeholder operational budgets
- 5.79% of total cost to the entire project paid by stakeholders.
- 94.21% of total cost will be externally funded.

CONCLUSIONS

1. Project partnerships and collaboration management is a WIN / WIN situation.
2. Simplified processes need to be created in applications
3. Better education and publication of joint funding applications is needed
4. This needs to be procedurally driven across organisations and not personality driven
5. A mindset on cost/benefit change is needed systemically across organisations
6. Funding provision commitment needs to be available for longer (2-5 year projects) to long term (5 year +) projects.

ALLOCATING RESOURCES TO MANAGE INVASIVE PLANT ERADICATION PROGRAMS

Oscar Cacho¹, Dane Panetta², Hillary Cherry³, Sue Bower⁴ Hank Bower⁵
and Susie Hester^{1,6}

¹UNE Business School, University of New England, Armidale NSW 2351

²School of Agriculture and Food, The University of Melbourne, Parkville, VIC 3010

³Pest and Weeds Team, National Parks and Wildlife Service, Hurstville, NSW 1481

⁴LHIB Flora Management Officer, ⁵ Manager Environment/World Heritage, Lord Howe Island, NSW 2898

⁶Centre of Excellence for Biosecurity Risk Analysis (CEBRA), Melbourne University, Australia

Email: ocacho@une.edu.au

SUMMARY The challenges of resource allocation faced by invasive plant managers arise from the need to use limited budgets as efficiently as possible. Within the expected budget, an agency must decide how to allocate resources to program coordination, different forms of surveillance, treatment, community engagement and research. Innovations on the technical side, as well as in public engagement and coordination between agencies, mean that eradications that were considered unfeasible in the past may be feasible now. In this paper, we argue that the success of a plant eradication program ultimately depends on the ability to find and kill individual plants. We present the basics of search theory to show why obtaining a measure of detectability is essential if we are to develop effective tools for allocating surveillance resources. We use examples from existing weed eradication responses to show how detectability is affected by environment, search mode and life stage of the plant. We conclude by proposing ways of making these decision-analysis principles more accessible to practitioners on the ground.

Keywords: surveillance, detection, eradication, decision analysis, search theory

INTRODUCTION

Eradication is defined as the elimination of every individual of a species from an area in which recolonization is unlikely to occur (Myers et al. 2000). This strategy is favoured wherever possible because the alternatives of containment or long-term control require ongoing investment (Zavaleta et al. 2001, Panetta and Timmins 2004, Grice et al. 2013). Rejmánek and Pitcairn (2002) maintained that eradication of infestations of >1000 ha was unlikely, given a 'realistic amount of resources', and subsequent research has tended to support this generalisation (Gardener et al. 2010, Howell 2012, Panetta and Cacho 2014). However, with further developments in surveillance and control methods, this limit may not apply. Innovations are occurring not only in the technical aspects of management but also in terms of coordination and collaboration between agencies, and in public engagement.

From an operational standpoint, the requirements for eradication are to delimit the incursion, halt reproduction, eliminate all remaining plants and exhaust the seedbank (Hamilton et al. 2015). Panetta and Timmins (2004) noted that feasibility of eradication must be viewed in the context of the amount of effort required to meet the objective. When

resources are unlimited, the upper boundary of eradication feasibility is set by the required effort at which eradication is no longer the most cost-effective management option (Panetta and Timmins 2004, Cacho et al. 2008). If eradication is deemed unfeasible with the resources available, containment may still be feasible. Understanding the characteristics of the weed and the environment it invades is essential in assessing this choice (Panetta and Cacho 2012, 2014). It is also important to note that containment is, in fact, a secondary objective in the case when eradication is the primary objective of an incursion management program (Wilson et al. 2017). The allocation decisions weed managers must make are the same whether eradication or containment is the primary goal, but the emphasis placed on particular aspects of the operation differ. There are many examples of coordinated weed management programs that aim to achieve eradication or containment; here we focus on eradication efforts.

THE ALLOCATION PROBLEM

The decision problem faced by invasive plant managers is illustrated (Figure 1). Within the expected budget, an agency must decide how to allocate resources to different forms of surveillance, treatment and research. Each of these actions can involve different activities. For example, in the case of treatment, targeted application of herbicide may be necessary in natural ecosystems whereas broad treatment is possible in cropping systems. Surveillance informs treatment (illustrated by a broken line in Figure 1) by assigning target areas. For surveillance in public lands, the typical case involves field officers (experts) searching for the weed in areas known or suspected to be invaded. Targeted treatment may occur simultaneously with surveillance, but it can also occur separately, as when contractors are sent later to spray. This form of surveillance may be supplemented by volunteers working under the guidance of field officers and, in some cases, informed by members of the public reporting sightings of the weed. Community engagement activities influence the effectiveness and cost of surveillance by attracting volunteers, and by enabling members of the public to recognise and report weeds (Hester and Cacho 2017). For large eradication efforts, a dedicated coordinator is required, and this is a significant fixed cost.

The use of detector dogs can be beneficial in situations where the weed is present at very low densities and/or is difficult to distinguish visually from the surrounding vegetation. Remote detection using satellites, drones or helicopters to collect photos or imagery can be used to pinpoint areas for treatment. Aerial surveillance is valuable when large search areas are involved, and for gaining access to inaccessible or remote sites. Aerial surveillance can also be combined with treatment when helicopters or drones apply herbicide directly to weeds as they are found (e.g. Leary et al. 2014).

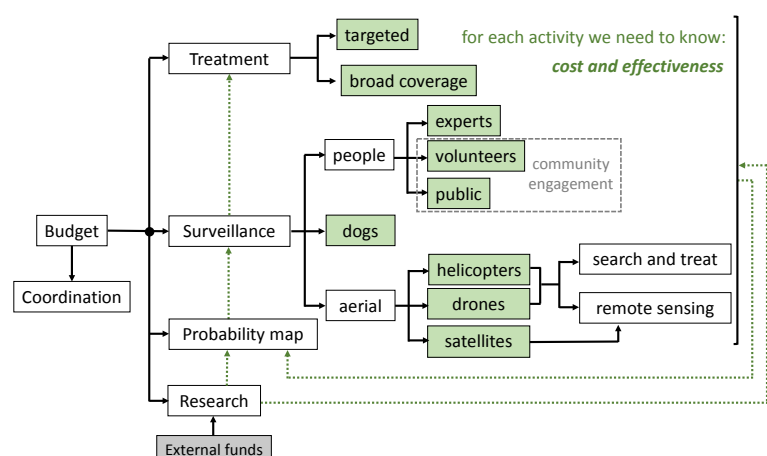


Figure 1. Conceptual model of the decision problem facing managers of eradication and containment programs. Dotted lines indicate transmission of information.

The incursion response is guided by a ‘probability map’ (Figure 1) based on the best information available. Ideally, the map would show the likelihood of weed presence in space, based on habitat suitability, proximity to known infestations and other factors (Hauser and McCarthy 2009). This information would guide surveillance and treatment efforts. The probability map can be improved over time as new surveillance and treatment information is incorporated. The feedback loop from surveillance to the probability map can be improved through additional research that combines data on the incursion with other information (e.g. biology/ecology of target weed). Not all research to improve either the probability map, or the effectiveness of particular activities, needs to be funded from the agency’s budget. Collaborations with academic institutions can provide access to additional research funds and expertise.

DETECTABILITY AND SEARCH THEORY

To solve the allocation problem, we need to know the effectiveness and cost of each mode of surveillance and treatment. Effectiveness is measured as the probability that a weed will be found when present (P_D) and the probability that a treated weed will be killed (P_K), in the case of surveillance and treatment respectively. The probability that a weed will be extirpated (P_E), from an area can be expressed as:

$$(1) \quad \text{Probability of extirpation } (P_E) = \text{probability of detection } (P_D) \times \text{probability of kill } (P_K)$$

The probability of detection for a random search path (Figure 2a) can be calculated as:

$$(2) \quad \text{probability of detection } P_D = 1 - \exp(-RSW)$$

The term within brackets in this equation is also called *coverage*, defined as

$$(3) \quad \text{coverage } C = RSW$$

Where: R = detectability (m); S = speed of search (m s^{-1}); W = search effort (s m^{-2}).

The detectability of a target can be calculated based on the detection profile, a representation of the searcher’s performance, showing the probability that the target will be detected as a function of its lateral distance from the searcher. The underlying assumption

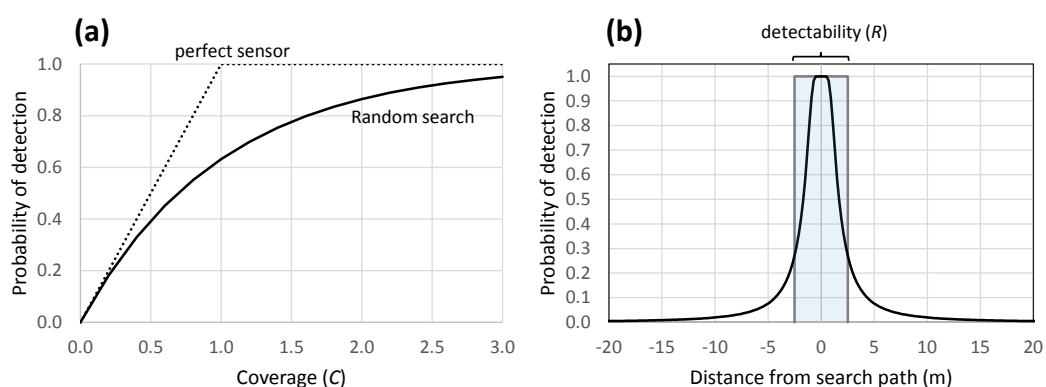


Figure 2. The probability of detection with a random search path compared to a perfect sensor that detects every target within its path (a). Lateral range curve (LRC) showing the probability that a target will be detected depending on its distance from the search path (b). The detectability factor (R) is calculated as the width of a rectangle whose area is the same as the area under the LRC. See Cacho et al. (2006) for details

is that the searcher detects a higher proportion of the targets that are close to the search path than those which are further away from the search path (Figure 2b). The efficiency of search per unit of distance covered is given by the area under the lateral range curve (see Cacho et al. 2006 for details).

In practice, the two key probabilities (P_D and P_K) are dependent on the resources available and how they are allocated. The variables that determine coverage can be related to costs, so being able to express the problem in this way allows us to come up with realistic estimates of what is possible with a given budget or, conversely, to justify budget requests for a target outcome (Cacho et al 2007). The *WeedSearch* model (Cacho and Pheloung 2007) provides a simple tool to assess eradication feasibility based on a small number of parameters related to biological and logistical aspects of the weed and the environment it invades. The model has been applied using informed estimates of weed visibility (Panetta et al. 2011), but more work is needed to understand how detectability is affected by surveillance method.

APPLYING THE MODEL

To solve the allocation problem we need estimates of weed detectability (R). The ability to detect a weed for a given search effort depends on the weed's visibility, time of day, fatigue, experience of the searcher, and search method.

Table 1. Detectability of weeds depending on growth form, habitat type and growth stage. Estimates are approximations based on Harris et al. (2001) and authors' experience. Life stages: seedlings (S), juveniles (J), mature (M), mature flowering or with flushing foliage (MF). Surveillance methods applicable for each life stage (see Figure 1): people: PE (experts), PV (volunteers-trained), PP (public -untrained); D (detection dogs); aerial: AH (helicopter – human visual sighting), AD (drones – remote imagery/video/photos), AS (satellites – remote imagery/photos). For these methods L, M, H and N refer to low, medium, high and no potential for detection.

Weed growth form (examples)	Habitat type	Life stage	Surveillance mode and level of Detectability						
			PE	PV	PP	D ⁺	AH [¥]	AD [¥]	AS [¥]
Tree or tall shrub Cherry guava	Forest	S	H	L	L	M	N	N	N
		J	H	L	L	M	L	L	L
		M	H	M	L	M	M	M	?
		MF	H	H	M	M	M	M	?
Shrub Bitou bush	Shrubland – including coastal dune habitat	S	M	M	L	M	N	N	N
		J	M	M	L	M	L	L	L
		M	H	H	L	M	H	H	M
		MF	H	H	H	M	H	H	M
Annual or herbaceous perennial Orange hawkweed	Open habitat*	S	M	L	L	M	N	N	N
		J	H	M	L	M	L	L	L
		M	H	M	L	M	L	L	L
		MF	H	H	M	M	M	M	L

* Open habitat includes grassland, river beds, sand dunes and other natural and induced open habitats.

+ Detectability estimates for dogs are based on olfactory (rather than visual) detection.

¥ Detectability estimates for aerial surveillance (AH, AD and AS) are based on scenarios where the weed has emergent foliage either above or in canopy.

Weed visibility is as much a function of the vegetation and terrain in which it occurs as of the characteristics of the target weed, which vary with phenology and growth stage. This means our detectability parameters need to account for search mode, environment, and plant characteristics as they change seasonally and with life stage. Table 1 combines these factors to illustrate how the problem could be tackled. Numerical values are not available but we indicate the relative detectability of selected weeds depending on life stage and surveillance method.

The visibility of weeds across different life stages has a significant impact on appropriate surveillance techniques. For example, mature bitou bush (*Chrysanthemoides monilifera* subsp. *rotundata*) is easy to spot, especially when flowering, but a seedling or juvenile is not. The pink bark of cherry guava trees (more prevalent on mature plants) and the new growth which flushes with a pink/reddish tinge contributes to its visibility. Cherry guava in a shrubland / heathland situation occurs on the upper slopes and edges of cliffs of LHI. In these cases the plant will form part of the canopy; combined with the flushing foliage this is a key to spotting, and treating, the target from a helicopter (AH in Table 1). Orange hawkweed (*Hieracium aurantiacum*) resembles a number of other native and introduced species, and is most detectable at flowering. However, it flowers and sets seed within several weeks, meaning that timely detection is critical (Constantine *et al.* 2016). The duration of maximum visibility during the year influences the temporal allocation of search effort, requiring periods of intense activity by staff and volunteers.

The use of dogs in the detection of weeds (D, Table 1) can increase our ability to detect plants before flowering, which reduces the risk of reproductive escape. McLean and Sargisson (2017) show that dogs can be effectively trained to discriminate specific weed species, and indeed trials in Kosciuszko National Park on detection of hawkweeds by dogs. An interesting case of public detections (PP in Table 1) occurs in Lord Howe Island (LHI), where 80-90% of the local population (350 inhabitants) would be able to detect a cherry guava (*Psidium cattleianum*). Long-term inhabitants of LHI have grown up with this weed, and have been involved in the campaign to eradicate it. However, detectability would be lower among new inhabitants or people returning to the island after long absences, or those who have not been involved in the eradication campaign.

Regarding aerial surveillance, drones (AD in Table 1) are proving useful in some situations. For example, the visibility of mature bitou bush by drones can be high, as the plant has a distinct leaf shape and colour, and is highly detectable using aerial photographs when in full flower. Drones in combination with automatic image recognition are being trialled for orange hawkweed in Kosciuszko National Park (Hamilton *et al.* 2015). As this technology improves it will increase the effectiveness and reduce costs of remote area surveillance and monitoring. While remote sensing may pick up sizeable infestations of weeds, it is unlikely to detect very small numbers of plants, particularly if these occur in the understorey (Panetta and Timmins 2004). However, multispectral imagery collected from drones and satellites may enable detection of small patches (~ 1m²) if the target weed has a unique spectral signature to other species in the invaded environment: this is currently being trialled for orange hawkweed.

Investments to develop effective and efficient coordination mechanisms play a key role in the success of these programs. For example, coordinated control strategies for bitou bush have resulted in two containment lines in northern and southern NSW, which supports eradication efforts in Queensland and Victoria (Cherry *et al.* 2008). A highly coordinated approach has ensured efficient management and enabled access to funding. These

programs are joint efforts involving Local and State authorities, as well as community groups. Community engagement plays an important role in these programs.

Research plays a critical role in the management of the weeds considered (Table 1). In the case of hawkweeds, considerable investments have enabled research on modelling and prioritising surveillance, developing effective herbicide techniques, and understanding the ecology and biology of the weed (Caldwell and Wright 2014).

It should be possible to create tables of detectability parameters for some of the major weeds based on search theory concepts. This would be the first step towards making the allocation model of Figure 1 operational.

CONCLUDING COMMENTS

There has been considerable progress since Panetta and Timmins (2004) noted the lack of quantitative approaches available to assess the feasibility of eradication. The probability that a plant invasion will be eradicated is strongly correlated to its detectability. It follows that understanding detectability is the key to developing operational models that can guide eradication efforts by allocating resources as efficiently as possible.

REFERENCES

- Cacho, O. J., Spring, D., Pheloung, P. and Hester, S. (2006). Evaluating the feasibility of eradicating an invasion. *Biological Invasions*, 8, 903–917.
- Cacho, O. J., Hester, S. M., and Spring, D. (2007). Applying search theory to determine the feasibility of eradicating an invasive population in natural environments. *Australian Journal of Agricultural and Resource Economics*, 51, 425–433.
- Cacho, O. and Pheloung, P. (2007). *WeedSearch: Weed Eradication Feasibility Analysis Software Manual*. CRC for Australian Weed Management Project 1.2.8. .
- Cacho, O. J., Wise, R. M., Hester, S. and Sinden, J. (2008). Bioeconomic modeling for optimal control of weeds in natural environments. *Ecological Economics*, 65, 559-568.
- Caldwell, J. and Wright, G. (2014). *Orange hawkweed control program report 2013/14*. Office of Environment and Heritage, New South Wales National Parks and Wildlife Service, Hurstville.
- Cherry, H., Willsher, L. and Whyte, B. (2008). Bitou bush and boneseed eradication and containment in Australia. *Plant Protection Quarterly*, 23(1), 38.
- Constantine, A., Hauser, C.E., Primrose, K. and Smith, N. (2016). Hawkweed (*Hieracium* spp.) surveillance: development of a targeted and robust plan for the Victorian Alps. *Plant Protection Quarterly*, 31(1), 28-32.
- Gardener, M. R., Atkinson, R. and Renteria, J. L. (2010). Eradications and people: lessons from the plant eradication program in Galapagos. *Restoration Ecology*, 18, 20–29.
- Grice, A., Clarkson, J. D., Murphy, H. T., Fletcher, C. S. and Westcott, D. A. (2013). Containment as a strategic option for managing plant invasion. *Plant Protection Quarterly*, 28(3), 62.
- Hamilton, M. A., Cherry, H. and Turner, P. J. (2015). Hawkweed eradication from NSW: Could this be 'the first'? *Plant Protection Quarterly*, 30(3), 110-115.
- Harris, H., Brown, J. and Timmins, S. (2001). Weed surveillance—how often to search? *Science for Conservation* 175, Department of Conservation, Wellington, New Zealand.
- Hauser, C. E. and McCarthy, M. A. (2009). Streamlining 'search and destroy': cost-effective surveillance for invasive species management. *Ecology Letters*, 12, 683-692.
- Hester, S. M. and Cacho, O. J. (2017). The contribution of passive surveillance to invasive species management. *Biological Invasions*, 19, 737-748.

- Howell, C. J. (2012). Progress toward environmental weed eradication in New Zealand. *Invasive Plant Science and Management*, *5*, 249–258.
- Leary, J., Mahnen, B. V., Cox, L. J., Radford, A., Yanagida, J., Penniman, T., Duffy, D. C. and Gooding, J. (2014). Reducing Nascent *Miconia* (*Miconia calvescens*) Patches with an Accelerated Intervention Strategy Utilizing Herbicide Ballistic Technology. *Invasive Plant Science and Management*, *7*(1), 164-175.
- McLean, I. G. and Sargisson, R. J. (2017). A dog as a generalist plant detection tool. *Weed Research*, *57*, 287-292.
- Myers, J.H., Simberloff, D., Kuris, A.M. and Carey, J.R. (2000). Eradication revisited: dealing with exotic species. *Trends in Ecology and Evolution*, *15*, 316-20.
- Panetta, F. D. and Timmins, S. M. (2004). Evaluating the Feasibility of Eradication for Terrestrial weed incursions. *Plant Protection Quarterly*, *19*(1), 5-11.
- Panetta, F. D., Csurhes, S., Markula, A. and Hannan-Jones, M. (2011). Predicting the cost of eradication for 41 Class 1 declared weeds in Queensland. *Plant Protection Quarterly*, *26*(2), 42-46.
- Panetta, F. D. and Cacho, O. J. (2012). Beyond fecundity control: which weeds are most containable? *Journal of Applied Ecology*, *49*(2), 311-321.
- Panetta, F. D. and Cacho, O. J. (2014). Designing weed containment strategies: An approach based on feasibilities of eradication and containment. *Diversity and Distributions*, *20*, 555-566.
- Rejmanek, M. and Pitcairn, M. J. (2002). When is eradication of exotic pest plants a realistic goal? In C. R. Veitch & M. N. Clout (Eds.), *Turning the tide: the eradication of invasive species* (pp. 249-253). Gland, Switzerland and Cambridge, UK: IUCN SSC Invasive Species Specialist Group.
- Wilson, J. R., Panetta, F. D. & Lindgren, C. J. (2017). *Detecting and responding to alien plant incursions*. Cambridge University Press, Cambridge, 1–265. <https://doi.org/10.1017/cbo9781316155318>
- Zavaleta, E.S., Hobbs, R.J. and Mooney, H.A. (2001). Viewing invasive species removal in a whole-ecosystem context. *Trends in Ecology and Evolution*, *16*, 454-9.

FIRE AND WEEDS – WHO’S TALKING?

Mark Graham¹, Kevin Taylor², Kate McShea³, Michelle Rose⁴ and Jennie Cramp⁵

- ¹ Hotspots Ecologist - North, Nature Conservation Council of NSW, 14/338 Pitt St, Sydney NSW 2000 Email: mgraham@nature.org.au
- ² Hotspots Ecologist - South, Nature Conservation Council of NSW
- ³ Coordinator, Hotspots Fire Project, Nature Conservation Council of NSW
- ⁴ Bush Fire Program Coordinator, Nature Conservation Council of NSW
- ⁵ Coordinator, Hotspots Fire Project, NSW Rural Fire Service, 15 Carter Street Lidcombe NSW 2141 | Locked Bag 17 Granville NSW 2142

SUMMARY Do our weed management plans and practices include adequate consideration of the interactions of wildfire, planned fire and weeds? It is clear that fire can create both opportunities and risks for those managing weeds. This presentation will focus on a recent Hotspots Fire Project review of the interactions between fire and weeds in native vegetation across NSW, and draw on case studies from the Blue Mountains and Cumberland Plains areas in Western Sydney. It will also provide an overview of key considerations of the interactions of fire, weeds and feral animal species that were raised during presentations and discussions at the Nature Conservation Council of NSW (NCC) Bushfire Conference (May 2017).

BACKGROUND

Based on best available science and operational knowledge, the Hotspots Fire Project (Hotspots) is a collaborative educational program for NSW landholders and land managers. The program aims to provide the skills and knowledge needed to actively and collectively participate in fire management planning and implementation for the protection of life, property and the environment. Hotspots is managed and delivered by the NSW Rural Fire Service (RFS) and NCC with the support of eight other partners*. As a scientific foundation to its workshops, Hotspots conducts literature reviews to investigate the interactions of fire and biodiversity across most of the state, excluding the far west. The reviews are then summarised and interpreted for a landholder-audience in the form of regionally specific booklets.

Over the past 12 years Hotspots has delivered workshops from the wet subtropical valleys of the Border Ranges along the NSW–Queensland border to the cold damp mountain tops of the southern tablelands and the semi-arid ranges of the lower Murrumbidgee Valley. Bushland and grassland weeds are present in all of these landscapes and present a myriad of costs, burdens and management challenges to the community. Fires (both wildfire and controlled burns) exert an influence on weeds within bushland areas. In many instances, or where used inappropriately, fire has been observed to exacerbate weed problems, whilst in a limited number of others, fire has been noted to provide beneficial outcomes for weed management. In general, there is a distinct lack of readily accessible materials documenting the interactions of fire and weeds within the native vegetation of NSW.

FIRE AND WEEDS IN THE NATIVE VEGETATION OF NSW REVIEW

In response to the interest in the interactions of fire and weeds expressed by landholders and professional natural resource managers, Hotspots conducted a state-wide review of available published materials, peer review journal articles, periodicals, grey literature, relevant expert opinion, unpublished data and case studies. The review does not investigate agricultural systems, exotic grasslands and other types of rural landscapes that lack native vegetation.

Fourteen weeds, including 6 Weeds of National Significance (WONS), were reviewed in detail (Table 1). These included major environmental weeds commonly occurring in each region or vegetation formation (Keith 2004) across NSW; including those that are known to significantly degrade native vegetation communities; or for which fire is known or suspected to exert a major influence on the weed species. For each of the weeds, there is a discussion of geographical occurrence in NSW, legal status, ecological attributes, preferred habitats and interaction with fire, a summary of key findings and management options.

Table 1. – Weeds reviewed in detail

African lovegrass (<i>Eragrostis curvula</i> (Schrad.) Nees)
African olive (<i>Olea europaea</i> subsp. <i>cuspidate</i> (Wall. ex G.Don) Cif.)
Bitou bush (<i>Chrysanthemoides monilifera</i> subsp. <i>rotundata</i> (DC.) Norl.)*
Blackberry (<i>Rubus fruticosus</i> species aggregate) *
Boneseed (<i>Chrysanthemoides monilifera</i> subsp. <i>monilifera</i> (L.) Norl.)*
Camphor laurel (<i>Cinnamomum camphora</i> (L.) T.Nees & C.H.Eberm.)
Chilean needle grass (<i>Nassella neesiana</i> (Trin. & Rupr.) Barkworth) *
Coolatai grass (<i>Hyparrhenia hirta</i> (L.) Stapf)
Lantana (<i>Lantana camara</i> L.) *
Phalaris (<i>Phalaris aquatica</i> L.)
Privet – large-leaved and small-leaved (<i>Ligustrum lucidum</i> Aiton and <i>L. sinense</i> Lour.)
Scotch broom (<i>Cytisus scoparius</i> subsp. <i>scoparius</i> (L.) Link)
Serrated tussock (<i>Nassella trichotoma</i> (Nees) Hack. ex Arechav.) *
South African pigeon grass (<i>Setaria sphacelata</i> var. <i>sericea</i> (Schumach.) Stapf & C.E.Hubb.)

* Denotes a WONS species

Of the 14 species reviewed most fell into two main categories; weeds for which fire promotes establishment or exacerbates an infestation (e.g. Coolatai grass), or weeds for which fire can provide positive management outcomes (e.g. bitou bush, lantana and South African pigeon grass). With the latter, the literature cited that exclusive use of fire rarely resulted in good restoration outcomes. The best results are achieved when fire is combined with other management interventions such as herbicide treatment. For many of the species reviewed there was a dearth of knowledge on interactions with fire or of the best combinations of management practices. The longevity of seeds in the soil seed bank and how they react to fire under different environmental conditions is an area where hard data is lacking. There is a need to build on this research to ensure better provision of

management advice, practical on-ground experiences and to drive better vegetation, biodiversity and bush fire risk management outcomes.

The Fire and Weeds in the Native Vegetation of NSW review has established a foundation which land managers, restoration practitioners, agency representatives and academics can draw on to improve fire and weed management practices across NSW. The information has been summarised and collated into a landholder booklet and the key findings and management options are being presented at Hotspots workshops around the state.

Bowen Mountain Case Study

Hotspots has been working with the Greater Sydney Local Land Services (GS LLS) to undertake restoration works at priority properties seeking to address Bell Miner Associated Dieback (BMAD). Restoration interventions included a two-day Hotspots workshop with participants gaining a better understanding of risk management, fire ecology and BMAD. Participants then developed property based fire and weed management plans, in cooperation with their neighbours. The group gained hands-on experience preparing a burn site, estimating fuel loads and reviewing fire behaviour, before observing a demonstration burn. Following the workshop, restoration interventions included a staged program of bushland regeneration and exploring potential for the use of fire to restore habitat values.

Multi-agency engagement and participation facilitated the development of 18 property fire and weed management plans, covering an area of 187 hectares. Funding was provided for native vegetation enhancement and stabilisation on four of these properties with Lantana and 11 other significant weed species removed. Property owners are now continuing this work and the use of fire has been recommended for two of these properties to stimulate native species and flush out weeds from the soil seed bank. Project benefits extend considerably beyond the immediate treatment zones, and in the longer term, aim to reduce the impact of BMAD in the northeast foothills of the Blue Mountains by improving native vegetation cover at restoration sites.

Using fire as a restoration tool in Cumberland Plain Vegetation Case Study

This restoration project was coordinated by the NCC's Bushfire Program and conducted within Cattai and Scheyville National Parks by the National Parks and Wildlife Service (NPWS), Western Sydney University and other project partners between 2013 and 2016. The trials examined a range of integrated fire and weed management treatments. Traditional protocols to manage African lovegrass suggest the use of herbicide and caution against the application of fire, due to the intense heat generated and the potential for resprouting. This innovative project provided an opportunity to test the potential benefits of integrated treatments combining fire and herbicide. Six different treatments were trialled at the two National Parks, across 48 plots over approximately 6 ha.

The results indicate that by combining fire and herbicide treatments, a better result is achieved than by using herbicide alone. The African lovegrass sward is removed and consumed by the fire, and the post-fire herbicide treatments limited further re-sprouting

and recruitment. The trials demonstrated that it is possible to break the dominance of African lovegrass, even in the most disturbed sites. It is possible that the benefits from applying these treatments will be even greater in less disturbed sites with better native recruitment potential. Applying these treatments in more disturbed sites will be of benefit when combined with supplementary planting of native species. However, it is still too soon to assess how the vegetation will develop following the trials and ongoing monitoring of the plots will continue.

Platforms for Further Discussion

Complementing the work of the Hotspots program the two most recent Bushfire Conferences hosted by the NCC Bushfire Program in 2015 and 2017, have addressed growing interest in the interactions of weeds and fire within native vegetation and supporting ecological restoration and bushfire hazard reduction activities. Several conference presentations focused on the importance of these interactions for specific weed species and highlighted research, strategic thinking and collaborative management approaches. The concept of better integration in management approaches also included how to take into account the interaction of fire with feral animals and their impact on native fauna.

The 2017 Bushfire Conference featured a panel discussion on these issues with policy and research experts contributing from the NSW Rural Fire Service, NSW Department of Primary Industries, Sydney University and NCC. The panel discussed how land and fire managers often plan and undertake management of fire, weeds and feral in isolation to each other, rarely considering the interaction of these processes in management plans and on-ground works. The tendency to operate in silos risks both worsening existing problems and the potential initiation of fresh challenges, as well as missed opportunities to improve management outcomes. As an outcome of the conference the NCC Bushfire Program will look for and encourage opportunities to promote greater collaboration and strategic thinking through research, adaptive management projects and consortiums.

A further outcome of the NCC conferences has been the establishment of the 'Fire and Restoration Network Hub', hosted and administered by the NCC Bushfire Program. The hub provides a valuable knowledge base and an experience-sharing portal for ecologists, bushland regenerators, land managers (both public and private), academics and landholders interested in the rapidly evolving area of ecosystem management.

Anyone interested in contributing to further discussions about the interactions of fire and weeds can provide links, suggest articles and start discussion topics on the Fire and Restoration site.

CONCLUSION

It is clear that the outcomes of a fire at any site will depend on site condition before the fire, prevalence and diversity of weeds in the landscape and the fire regime. Post-fire, one of the most important land management considerations is the significant difference weed control and bushland regeneration can have on the trajectory for recovery, regeneration and long-term condition across sites and landscapes. There is a critical need to continue to trial treatments (and combinations of treatments), to monitor and review the results and to collate and distribute information on the best management practices and optimal fire regimes. This will ensure effective bush fire hazard reduction is achieved along with improved management outcomes for weeds across the state.

ACKNOWLEDGEMENTS

*Hotspots Fire Project – jointly managed and delivered by the NSW Rural Fire Service and the Nature Conservation Council of NSW. Hotspots project partners: Office of Environment and Heritage, National Parks and Wildlife Service, Local Land Services, Forestry Corporation, NSW Farmers, Local Government NSW, South East Queensland Fire and Biodiversity Consortium and the University of Wollongong.

www.hotspotsfireproject.org.au

NCC Bushfire program – Funding partially from the NSW Rural Fire Service.

<http://www.nature.org.au/healthy-ecosystems/bushfire-program/conferences/2017-ncc-bushfire-conference/>

Fire and Restoration Network hub - <http://fireandrestoration.org.au/> Established with initial support from the Norman Wettenhall Foundation.

Bowen Mountain Hotspots workshop - Restoration funding provided by the Greater Sydney Local Land Services through the Australian Governments National Landcare Program.

Using fire as a restoration tool in Cumberland Plain Vegetation project - Funded by the NSW Environmental Trust, the project included the National Parks and Wildlife Service, Western Sydney University, Nature Conservation Council of NSW, Muru Mittigar, Australian Association of Bush Regenerators, and Aquila Ecological Surveys.

<http://fireandrestoration.org.au/african-lovegrass-2/>

REFERENCES

Keith DA (2004) Ocean Shores to desert dunes: the native vegetation of New South Wales and the ACT. Department of Environment and Conservation (NSW), Hurstville, NSW.

COLLABORATION, COOPERATION AND TEAMWORK TO IMPROVE THE CONDITION OF BIODIVERSITY ASSETS IN THE NORTH WEST.

Peter Dawson

Senior Land Services Officer, North West Local Land Services, Tamworth, NSW 2340, Australia.
Email: peter.dawson@lls.nsw.gov.au

SUMMARY:

Since the inception of North West Local Land Services in January 2014 weeds professionals from across the region have been working together on coordinated rapid response and strategic control programs to improve the condition of priority Regional Vegetation Communities within the North West local Land Services (NW LLS) regional boundary.

Keywords: Threatened or endangered ecological communities (TECs & EECs) and Regional Vegetation Communities (RVCs)

INTRODUCTION

A number of vegetation communities in the NWLLS region are listed as TECs under the Environment Protection and Biodiversity Conservation Act 1999 and or EECs under the Threatened Species Conservation Act 1995.

The NW LLS Biodiversity Prioritisation Plan 2015 identifies invasive species as a key threat to native flora and fauna through predation, competition for resources and habitat disturbance amongst others. In response NW LLS has been investing in the targeted control of invasive weeds in priority biodiversity assets within the North West region.

APPROACH:

Over a 3 year period Catchment Action NSW has enabled NW LLS to enter into partnership agreements with Local Government Control Authorities to manage high risk weed pathways. These projects, developed in conjunction with local Weed Officers and NW LLS staff, will result in the removal of key emerging non-native invasive species from high use routes across the North West region.

Investment in these partnership programs will maintain or improve the condition of native vegetation and biodiversity assets. Targeted RVCs include critically endangered Grassy White Box Woodlands and Box - gum grassy woodland communities along identified roadside vegetation corridors.

These pathways include high use roads and highways, stock routes, railways and major watercourses, which all have the potential for weed distribution through the movement of machinery, livestock, native and feral animals and water.

The high risk pathways being targeted include the New England Highway from Willow Tree to Uralla; Fossickers Way from Tamworth to Bingara; and, Horton Road from Cobbadah to Horton village.

These roads have a high movement of vehicles and machinery in and out of the region as well as many of them contributing to North West stock routes.

The objective is to manage key threatening processes particularly emerging or high priority weed species at the controllable level before they cross the threshold where control of spread is no longer an option. Additional on-ground interventions may include restoration works through regeneration or revegetation.

Target species include, but are not limited to:

- Honey locust (*Gleditsia tricanthus*)
- Feral fruit and nut trees;
- Chinese pistachio (*Pistacia chinensis*);
- African olive (*lea europaea* subsp. *Cuspidate*)
- Oleander (*Nerium oleander*);
- Century plant (*Agave spp*);
- Bridal creeper (*Asparagus asparagoides*);
- Firethorns including Hawthorn (*crataegus monogyna*, *Cotoneaster spp.*, *Pyracantha spp*)

These species are considered key emerging or high priority widespread invasive species under the NWLLS Transition Catchment Action Plan and identified in the NW LLS Invasive Species Prioritisation and Implementation Framework 2015.

The main on-ground interventions are chemical control works utilising cut stump, basal bark and overall spray techniques in order to minimize any off target impacts. Annual follow up control works can be integrated into council's seasonal roadside weed control programs.

Key Stakeholders include:

- Private landholders in the NWLLS region;
- Public land owners/managers in the NWLLS region;
- NW LLS staff;
- NSW Department of Primary Industries;
- Local Weed Control Authorities;
- Weed control contractors; and
- Landcare Groups

Projects also include education and capacity building components to inform landholders of the intent of the projects. This includes media releases and the delivery of local field days providing information on the biology, importance of control and when and how best to control these weed species within their particular location and context.

These programs also enable land managers to participate in on-ground works and improved management programs that will support the resilience of priority native vegetation assets across the region.

Landholder commitments include;

- Providing clear access to project sites;
- Water supply;
- On-going monitoring and follow-up control
- Coordinated Farmer Army undertaking control programs for Hudson Pear and *Harrisia Cactus* across the region.

Collaborative weed control projects July 2014 to June 2017 include;

- Gunnedah, Gwydir, Liverpool Plains and Tamworth Councils integrated control of identified key emerging and high priority widespread weeds on high risk pathways.
- Gwydir Shire Council removal of an existing outbreak of *Sagittaria (sagittaria platyphylla)* on the Gwydir River at Bingara.
- Narrabri and Moree Plains, Shire Councils, inspection, surveillance, monitoring and control activities for Green Cestrum (*Cestrum Parqui*) within the riparian zones along the Gwydir River, Slaughterhouse and Eulah creeks.
- NSW DPI NWLLS 2015 Hudson Pear biological control agent release strategy.
- Joint Venture with NSW DPI Weed Research Unit (WRU) for the sub-project: Biological control of Mother-of-Millions (MoM), which forms part of the rural R&D for Profit Project to be submitted by Rural Industries Research and Development Corporation (RIRDC).
- Tamworth Regional Council Espartillo, Madeira vine, Halls Creek Honey Locust and Oleander control programs.
- Gunnedah Shire Council Honey locust, Alligator Weed & Gwydir River inspections.
- Moree Plains Shire Council Control activities, including mapping, monitoring and control of Water Hyacinth in the Gingham Channel.
- Inland Weed Control of Mother of Millions (*Bryophyllum delagoense*) within TECs along the Newell Highway south of Narrabri.
- Coordinating integrated weed control programs for Hudson Pear and *Harrisia Cactus* across the region.

Investment to date;

NWLLS = \$842,725.41

In-kind = \$592,049.11

Total = \$1,434,774.50

Total area = 6257 ha

Average cost =\$229.30/ha

CONCLUSION:

When engaging landholders to manage remnant native vegetation communities for biodiversity outcomes it is often difficult to quantify direct positive economic benefits however when the community is targeting high risk species for eradication or at least reducing the distribution and density there is a positive return on investment for all parties.

The successful control of these species will help improve the condition of native vegetation in priority biodiversity assets by reducing the impact of invasive species on threatened species and TECs within the NW LLS region.

These partnerships require collaboration, cooperation and teamwork from all stakeholders to achieve successful outcomes. By identifying common ground, recognising shared responsibilities and being part of the solution these programs will continue to strengthen the relationship between State and Commonwealth investors, Local Land Services, local government and more importantly, local communities to effectively manage key emerging and priority widespread invasive species into the future.

REFERENCES

North West LLS Biodiversity Prioritisation Plan 2015

North West Regional Strategic Weed Management Plan 2017-2022

North West LLS Local Strategic Plan 2016-2021

North West LLS Transition Catchment Action Plan

Eco Logical Australia 2015. *Invasive Species Prioritisation and Implementation Framework*. Prepared for North West Local Land Services.

**PLANT SURE:
AN ENVIRONMENTALLY SAFE ORNAMENTAL PLANT SCHEME**

Stephen B. Johnson¹, Hillary Cherry² and Des Boorman³

¹Weed Ecologist, Weed Research Unit, New South Wales Department of Primary Industries, Locked Bag 6006, Orange, NSW 2800, Australia

²Weed Management Officer, Pest and Weeds Team, National Parks and Wildlife Service, PO Box 1967, Hurstville, NSW 1481, Australia

³Program Manager for Plant Sure, Nursery and Garden Industry of New South Wales and the Australian Capital Territory, PO Box 3013, Rouse Hill, NSW 2155, Australia

SUMMARY

The vision of the Plant Sure initiative is to reduce the use of high risk (weedy) ornamental plants through a self-sustaining, voluntary accreditation or certification scheme. This paper explains the Plant Sure initiative, managed by the consortium lead by the Nursery and Garden Industry of NSW and ACT, and invites you to participate in its development, implementation and future success.

Invasive plants (weeds) are a significant threat to biodiversity and the environment. The Plant Sure initiative will prevent future environmental impacts from weeds by reducing the availability of high risk (weedy) ornamental plants from production, supply, and trade by engaging with government, industry and the community, to develop an agreed decision support tool for ornamental plants. This will build on existing efforts such as ‘Grow Me Instead’, the ‘Bushland Friendly Nursery Scheme’, the Nursery and Garden Industry of Australia’s ‘Invasive Plant Risk Tool’ and the NSW ‘Weed Risk Management System’. Plant Sure will develop extensive branding and engagement strategies to elicit changes in consumer behaviour.

An agreed decision support tool will allow plants to be categorised according to risk; and plants that pose a high risk of becoming weeds can be excluded from use. Conversely, the use of environmentally-safe plants can be encouraged and promoted. The assessment process will also assist the Green Life industry sectors to maintain diversity and interest in ornamental plants by allowing a more proactive approach in assessing new plant introductions to ensure they are environmentally friendly.

The ornamental plant decision support tool will be used to underpin the development of a ‘national-ready’ and ‘sector ready’ voluntary accreditation or certification scheme (the Scheme) to engage Green Life industry sectors in promoting environmentally-safe plants and to avoid using plants that pose an environmental weed risk. The Scheme will provide confidence to industry and consumers that their plant choices are safe for the environment. It will allow industry to showcase their environmental stewardship and to develop strong brand awareness that supports a ‘self-sustaining’ independent Scheme open to all industry sectors. By including education and training components, the Plant Sure Scheme will seek to elicit long-term attitudinal and behavioural change in ornamental plant suppliers and

consumers, and increase community knowledge and awareness of environmental weed issues.

Keywords: Weeds, invasive plants, weed risk, environmentally-safe, assessment, accreditation, certification, Green Life industry, decision support tool.

BACKGROUND

Weed invasions have significant impacts, including to the environment and biodiversity. For example, a seminal NSW study showed that weed invasions were second only to land clearing in impacting threatened biodiversity (Coutts-Smith and Downey 2006). Further, analysis found that weeds threaten around 45% of vulnerable and endangered species in NSW and 89% of the state's endangered ecological communities (NRC 2014). Plants that escape from gardens and naturalise are a significant source of environmental weeds. Globally, the ornamental plant trade is the predominant pathway of weed spread, with at least 20,773 (47%) ornamental plant taxa recognised as weeds (Randall 2017). The proportion is greater when naturalised plants are considered: over 65% of introduced plants that have naturalised in Australia are considered garden escapes (Virtue *et al.* 2004); and 75% of those species in NSW recorded since 2000 (unpublished data).

Accordingly, there is a strong desire in industry, government and the community to reduce the use of weedy ornamental plants and prevent future environmental weeds (e.g. NRC 2014). Over the last 10-15 years, several initiatives at national, state and regional levels have attempted to provide a mechanism to discourage the use of plants that have a risk of becoming environmental weeds. However, previous initiatives, including those led through *industry, advocacy, or government, have not delivered long-term or far-reaching outcomes*. This project aims to address a key gap in previous initiatives by developing a *purpose-built ornamental plant decision support tool (OPDST) that determines the environmental weed status* (i.e. at 'risk' or 'safe' for the environment) for ornamental plants. This process will be agreed by industry, government and community stakeholders, giving it the cross-tenure support necessary for broad acceptance and use. It seeks to engage users of ornamental plants and educate them about the potential weediness of certain plants as assessed through the OPDST. The OPDST will be a foundational tool used in implementing the voluntary accreditation or certification scheme (herein referred to as 'Scheme') to engage industry in removing plants from trade or use that are a risk to the environment. The Scheme seeks to reduce consumer demand for ornamental plants that could become weeds. A critical component is education and engagement so that people can make informed decisions about their ornamental plant purchases.

There are several projects that have created similar schemes to facilitate broad stakeholder engagement between those involved in the production/use of ornamental plants, and government agencies, universities, weed control agencies and environmental organisations (both private and public), and organisations associated with addressing invasive species issues. Plant Right California (PRC 2007-2011, Conser *et al.* 2015) and University of Florida Institute of Food and Agriculture Sciences UF/IFAS (2017) are two such models that have been successful in creating the important linkages between industry and plant

consumers to effectively reduce the demand for identified weedy plants. Both have used different approaches and have their strengths and weaknesses but both demonstrate the need for broad engagement, collaboration and agreed actions to be successful.

The Scheme will use a voluntary compliance approach: as such, it needs to create and promote a strong brand awareness to get the uptake required to achieve the desired result. Having said this, it will be designed to complement existing regulation by providing the Green Life industry with mechanisms to demonstrate compliance to the General Biosecurity Duty under the NSW *Biosecurity Act 2015* by reducing or removing the weed risk associated with some plant introductions.

WORKING TOGETHER

Being voluntary, this Scheme will include mechanisms to engage with consumers and educate the community more generally, as well as engaging with the Green Life industry to ensure awareness and to promote a reduction in production and demand for identified weedy plants.

This project will work collaboratively with the Green Life industry, led by the Nursery and Garden Industry of NSW and ACT and the Australian Institute of Horticulture, including the nursery, gardening and horticulture sectors, to develop and introduce the voluntary Scheme to reduce existing, or to abate future weed risks from ornamental plants by identifying those species that may impact the environment (i.e. 'high risk' species) and reducing their supply and demand in NSW. Scheme development will *consider the entire ornamental plant 'supply chain', including specification, production, supply, sale and installation, as well as end user groups, such as government bodies that approve or recommend plants for use.* The Scheme and assessment process will include audit and review processes to guide standards to ensure accountability. Additionally, the Scheme will include concurrent education and training components to elicit behavioural change in ornamental plant consumers and producers, as well as encourage broader public participation. *The Scheme will be developed to address the triple-bottom line, with the aim to minimise risks to the environment, maximise economic benefit to industry, and engage the community and industry in understanding the impacts of weeds and making 'environmentally-safe' plant choices.*

HOW THIS PROJECT WILL BE CARRIED OUT

The project has two phases. Phase 1 is foundational research, scoping and development. It will investigate existing:

- 1.1) accreditation and certification programs and Standards across a range of industry sectors to determine best practice and identify successful models; and develop a fit for purpose voluntary Scheme model to be refined by all stakeholders in Phase 2; and
- 1.2) plant and weed risk assessment tools and prioritisation processes, and develop and test a purpose-built assessment process to support the project objectives.

The process will include the OPDST that allows the categorisation of plants into ‘safe’ or environmental ‘high risk’ categories, which will be used to underpin the Scheme (i.e. safe plants will be promoted by Scheme participants, while ‘high risk’ plants will be voluntarily removed from sale/use).

Phase 2 is largely implementation, and will integrate the tools developed in Phase 1 to:

- 2.1) use the recommended model to develop the Scheme, including associated communication and engagement platforms, ‘branding’ and promotion;
- 2.2) assess plants currently used by industry to categorise plants as either ‘high risk’ or ‘safe’ species;
- 2.3) develop audit and compliance capability for Scheme members;
- 2.4) engage and train industry participants in the Scheme; and
- 2.5) develop and implement consumer and industry behaviour change campaigns, and public awareness initiatives.

PHASE ONE IS NOW UNDERWAY

Phase 1 of the project began in January 2017, and below is a detailed explanation of the two components being undertaken in Phase 1. Following this, we explain how you can be involved.

Phase 1a: Development of a purpose-built Plant Assessment Process

Foundational to the overall success of this project is the development of an agreed assessment process to determine the environmental weed risk of ornamental plants. The process will also categorise plants based on their level of weed risk including the development of the OPDST.

The development of the OPDST involves four stages.

1. **Literature review.** The literature is being examined to identify and review existing national and international plant risk assessment, decision support and categorisation tools/processes. They will be assessed on their ability to provide transparent, reproducible assessments of the environmental weed risk of any ornamental plant, including hybrids, varieties, cultivars and intraspecific variation, where feasible. The critical design parameters for the OPDST are outlined (Appendix 1).
2. **Refine and/or adapt.** Based on the literature review, one or more of the existing tools and/or systems will be refined and/or adapted to develop the OPDST for use in the Plant Sure project. This will allow risk assessment of ornamental plants, and categorisation based on their level of environmental weed risk in Australian conditions. This activity will be done in consultation with the broadest range of possible stakeholders to ensure it meets community, industry and government needs (and can be readily adapted for use by other industries or jurisdictions).

3. **Trial the model decision support tool.** This trial aims to validate and calibrate the tool and will be done using known ‘weeds’ and known ‘safe’ ornamental plants, as well as ornamental plants whose environmental weed status in Australia is currently unknown so to test the predictive ability of the process. The trial will include assessment of hybrids, varieties, cultivars and intraspecific variation, where feasible.. Where possible, weedy/non-weedy analogues within the same genus or species will be used for comparison.
4. **Liaison and adoption.** Extensive consultation will occur throughout the development of the OPDST. This will be led by the project consortium, and include project reference group members (see below) and a wide range of other stakeholders. The consortium will organise meetings and workshops, including with cross-jurisdictional stakeholders, to help ensure the OPDST and Plant Assessment Process is fit for purpose.

Phase 1b: Development of a ‘national-’ and ‘sector-ready’ voluntary accreditation or certification scheme (the Scheme)

The OPDST (and process) will be a crucial component within the overall voluntary accreditation or certification scheme (the Scheme). Having said this, engagement and communication components (including branding), are critical to the success of the Scheme in the wider community.

The development of the voluntary scheme will involve three stages.

1. **Literature review.** The literature will be examined to identify and review existing voluntary accreditation or certification programs and Standards for similar style projects across a range of industry sectors. The aim of these investigations will be to determine what components should be included in the Scheme, and what type of Scheme will be most effective (e.g. accreditation or certification) to achieve project objectives. Successful models will be industry best practice and have high levels of useability, transparency, adaptability and, ideally, meet the range of critical design parameters (Appendix 2).
2. **Develop or align.** A crucial element for a fit-for-purpose voluntary Scheme model(s) will be the development or alignment of the proposed Scheme with a recognised standard. This will include identification of the most appropriate level of governance and justification for the recommended model Scheme. Again, this activity will be done in consultation with the broadest range of possible stakeholders to ensure it meets community, industry and government needs (and can be readily adapted for use by other industries or jurisdictions).
3. **Pilot or test the Scheme.** The proposed Scheme will be piloted/tested with the nursery, gardening and horticulture sectors, as well as engaging a range of other Green Life industry sectors (e.g. landscaping and design industries, and other plant ‘user’ groups, such as Local Government) to ensure the Scheme is usable by all relevant sectors, and is also ‘National ready’, via engagement with stakeholders from other States and Territories.

HOW YOU CAN BE INVOLVED

The Plant Sure project is supported by the NSW Environmental Trust, and is currently managed through the consortium led by the NGINA, in conjunction with the NSW Department of Primary Industries (DPI), Office of Environment & Heritage (OEH) and the Australian Institute of Horticulture (AIH). The project is guided by a Reference Group that represents a variety of different interests from industry, government and the community. The Reference Group currently includes environmental interest groups, university researchers, Local Control Authorities, Australian Association of Bush Regenerators, Local Land Services, and Local Government NSW. The consortium is actively seeking participation from other interested stakeholders, including from other jurisdictions and across wider Green Life industry sectors, to contribute to the development, implementation and adoption of the Scheme. The role of stakeholders will be to help build and 'test' the assessment process and Scheme, to make sure they are fit for use across each stakeholders respective group or industry.

There are many ways that you can be involved, and a wide variety of levels of involvement (from attending workshops or teleconferences, to providing comments or ideas on one or more components as they develop), and we welcome any input. Please contact any of this paper's authors for more information (see contact details immediately after the Acknowledgements section).

Broad stakeholder engagement is a key component of this project to ensure wide acceptance and wide reach for support and implementation of the Scheme. We hope you will join us in this important endeavour to enhance the green-life industry and protect the environment from future weed impacts.

ACKNOWLEDGMENTS

This research is funded by the New South Wales Environmental Trust (NSW ET). We acknowledge the efforts of the NSW ET, particularly Program Manager Leanne Hanvey, as well as the contributions of a range of stakeholders who serve on the reference group.

CONTACT DETAILS

The Plant Sure scheme consortium and communications manager can be contacted as follows:

Des Boorman
Project Manager
Officer
Nursery and Garden Industry NSW and ACT
and ACT
PO Box 3013, ROUSE HILL 2155
T: 02 9679 1472
M: 0427 775 086
E: des.boorman@ngina.com.au

Michael Danelon
Business and Technical Support
Nursery and Garden Industry NSW
PO Box 3013, ROUSE HILL 2155
T: 02 9679 1472
M: 0400 010 049
E: michael.danelon@ngina.com.au

Hillary Cherry
Weed Management Officer
NSW National Parks and Wildlife Service
PO Box 1967, HURSTVILLE 1481
T: 02 9585 6587
M: 0427 104 448
E: hillary.cherry@environment.nsw.gov.au

Wayne Van Balen
President
Australian Institute of Horticulture
5 Appletree Drive, CHERRYBROOK 2126
T: 029484 8400
E: wayne.vanbalen@aih.org.au

Stephen Johnson
Weed Ecologist
NSW Department of Primary Industries
Locked Bag 6006, ORANGE 2800
T: 02 6391 3960
M: 0418 415 821
E: stephen.johnson@dpi.nsw.gov.au

Aimee Freimanis
Plant Sure Communications Manager
EcoHort Pty Ltd
T: 02 9894 2418

E: aimee@ecohort.com

REFERENCES

Conser, C., Seebacher, L., Fujino, D.W., Reichard, S. and DiTomaso, J.M. (2015). The development of a Plant Risk Evaluation (PRE) tool for assessing the invasive potential of ornamental plants. *PLoS ONE* 10(3): e0121053. doi:10.1371/journal.pone.0121053

Coutts-Smith, A.J. and Downey, P.O. (2006). 'Impact of weeds on threatened biodiversity in New South Wales'. Technical series no.11. Cooperative Research Centre for Australian Weed Management, Adelaide. 98 pp.

HB203:2012 Standards Australia/Standards New Zealand (2012). Managing environment-related risk. (Standards Australia International, Sydney and Standards New Zealand, Wellington).

HB294:2006 Standards Australia/Standards New Zealand/Cooperative Research Centre for Australian Weed Management (2006). National Post Border Weed Risk Management Protocol. (Standards Australia International, Sydney and Standards New Zealand, Wellington).

ISO31000:2009 Standards Australia/Standards New Zealand (2009). Risk management - Principles and guidelines. (Standards Australia International, Sydney and Standards New Zealand, Wellington).

NRC, Natural Resources Commission (2014). Weeds – Time to get serious. Review of weed management in NSW. Final report and recommendations. <http://www.nrc.nsw.gov.au/publications> (accessed 17 July 2017).

PRC, Plant Right California (2007-2011). <http://www.plantright.org/> (accessed 21 July 2017).

Randall, R.P. (2017). *A Global Compendium of Weeds*. 3rd Edition. R.P. Randall, Perth, Western Australia.

UF/IFAS, University of Florida/Institute of Food and Agricultural Sciences (2017). Assessment of non-native plants in Florida's natural areas. <https://assessment.ifas.ufl.edu/> (accessed 21 July 2017).

Virtue, J.G., Bennett, S.J. and Randall, R.P. (2004). Plant introductions in Australia: How can we resolve 'weedy' conflicts of interest? Proceedings of the 14th Australian Weeds Conference, eds. B.M. Sindel and S.B. Johnson, pp. 42–8. (Weed Society of New South Wales, Wagga Wagga). <http://caws.org.au/awc/2004/awc200410421.pdf> (accessed 20 July 2017).

Appendix 1

Critical design parameters for the ornamental plant decision support tool (OPDST).

The ornamental plant decision support tool (including plant risk assessment and categorisation processes) will, but will not be solely restricted to, the following:

1. be scientific best practice;
2. be based on, or significantly applicable to, current standards and handbooks for assessing environmental and plant risk (e.g. HB294:2006, and its revisions, as well as ISO31000:2009 and HB203:2012). This will require the assessment of the most relevant existing plant and weed assessment tools and categorisation frameworks used in Australia and globally, including current literature and developments to ensure the best models are examined;
3. be transparent in how categorisations are obtained, including the ability to store, view and update the data used in the assessment process in an open access platform;
4. have mechanisms in the assessment process to deal with 'uncertainty' or lack of data;
5. have the ability to 'categorise' plants (e.g. using a traffic light approach, or according to a point system);
6. have a transparent and clear description of the 'categorisation' system (e.g. if traffic light approach, what defines 'red' or 'green'; if point system, what are the 'cut off' points, etc);
7. be readily understood and usable by a range of users, including from Green Life industry sectors, government and the community (that is, anyone can use it to assess plants while still maintaining the rigour of the assessment process);

8. be applicable (and/or adaptable) for use by all Green Life industry sectors; and in other jurisdictions in Australia/New Zealand;
9. be dynamic (e.g. when more data is available for a species, the assessment can be easily updated);
10. be applicable to all plants (Kingdom Plantae) including known weeds, and plants not yet known to be weedy;
11. contain an initial risk assessment 'screen' that can be used to quickly assess those species that are documented weeds (e.g. weeds prohibited by legislation could be "rejected" without undertaking a full plant risk assessment);
12. allow assessment of species in a variety of bio-climatic zones;
13. allow assessment of hybrids, varieties, cultivars and intraspecific variation (or where this is not possible, contain a mechanism to recognise these taxa and identify the information needed for future assessment);
14. include methods to assess risks associated with hybridisation, genetic pollution and taxonomic/genetic relatedness (including via conventional breeding and natural processes) and risk of genetically modified material; and,
15. be inclusive of a range of triple bottom line considerations, that is
 - a. economic, including impacts to green-life industries (and impacts on other primary industries); and
 - b. environmental, including to non- and threatened biodiversity; and societal, including human and animal health, community, cultural, infrastructure, tourism and other considerations.

Appendix 2

Critical certification or accreditation Scheme design parameters

To deliver a robust and credible Scheme, the following design parameters are considered critical, and although not exclusive, include the following:

1. develops a brand that is easily identifiable and inspires consumer confidence;
2. provides equitable access to relevant businesses, regardless of size, type, industry sector, or location, to participate in the Scheme;
3. will involve stakeholder mapping to demonstrate understanding of the industry sectors and will include growers and producers, major plant wholesalers, retailers, stakeholders who influence species selection, and household and commercial (industry/government) consumers. A complete chain of custody (ornamental plant supply and demand chains) will be considered as part of the stakeholder mapping process;

4. is non-exclusive and open to all industry sectors;
5. includes a standardised, simple and easy approach to industry and consumer stakeholders;
6. is transparent, independent, and robust, and uses best-practice and appropriate governance;
7. appeals to industry stakeholders and is sustainable for them, both environmentally and economically;
8. is independent and self-sustaining, such that it “takes on a life of its own” and is run ‘outside’ of industry, but for industry;
9. enables broad stakeholder engagement and consultation with a view to broad industry uptake, commitment and ownership of the Scheme;
10. encompasses independent expertise to develop appropriate Standards, audit and compliance processes, and education elements;
11. is based on the agreed decision support tool that is dynamic and will allow plants to be reassessed as needed to determine weed risk;
12. allows a transitional approach to removing ‘high risk’ species from trade over a 12-18 month period (or as determined appropriate via consultation);
13. utilises an agreed categorisation and prioritisation of ‘high risk’ plants for removal from trade;
14. allows for collaboration with similar programs and projects to share knowledge and resources, identify synergies and opportunities and avoid duplication;
15. contains robust consumer and industry education and awareness methodologies to promote the Scheme and its objectives;
16. is able to be adapted or expanded to a cross-jurisdictional/National level, and for other industry sectors following completion of this project;
17. includes the development of a business plan or management model to ensure ongoing Scheme viability plus future proofing of Scheme ownership and branding;
18. includes transparent and appropriate audit and compliance processes;
19. includes options for an ‘institutional home’ for the Scheme over the long term;
20. includes mechanisms for conflict resolution for industry, government and the community; and
21. ensures focus on positive environmental and economic outcomes, as well as social and behavioural change regarding use of weedy species, and be inclusive of a range of triple bottom line considerations such as:
 - a. economic, including impacts to Green Life industry sectors (and impacts on other primary industries); and
 - b. environmental, including to non- and threatened biodiversity; and societal, including human and animal health, community, cultural, infrastructure, tourism and other considerations.

UAVs Another Tool for the Weed Controller

Philip Milling

6 Rosin Place, Bolwarra Heights NSW 2320

Email: phil@skylandmanagement.com.au

SUMMARY Unmanned Aerial Vehicles (UAVs) continue to grow in popularity to improve efficiency and effectiveness in many industries. Most of the uses of UAVs to date have involved mapping, land surveying, photography, site monitoring and recording. When it comes to weed control, to date the applications have been restricted.

Using a medium sized rotary wing UAV with a high payload capacity, specifically designed for aerial application of both liquid or granular products, primarily herbicides, provides another tool in the toolbox of the weed controller. Understanding the unique capabilities different technologies bring with them, in this case UAVs, means weed control that previously seemed too difficult, unsafe and/or costly, becomes viable.

A current trial being conducted by Sky Land Management and DPI Tocal Agricultural College is using a high payload UAV for the application of herbicide to control *Arundo donax* (Giant Reed). This is a major weed of several main rivers in the Hunter Valley (NSW) that is a major problem and is rapidly spreading. The cost and effectiveness associated with controlling Giant Reed using traditional methods such as ground spraying or manual removal is inherently expensive and in many cases, can create significant stream bank disturbance.

Using the UAV as a tool to apply herbicide from above has enabled deep and full application of herbicide. Results to date have shown 80-90% death of Giant Reed after a single treatment using glyphosate. A larger scale trial will take place in April in conjunction with Hunter Local Land Services. The next phase of this trial will employ the oldest weed management tool, fire, to reduce the biomass. The intention is then to respray the regrowth post burning. Site rehabilitation will include direct seeding of suitable riparian flora, applied using the UAV.

Understanding technology and its applications can provide weed managers with efficient and effective options which have not been available in the past. Combining the latest of technologies with tried and true methods can significantly enhance our weed management efforts.

INTRODUCTION

Arundo donax commonly known as giant reed [sometimes call Elephant grass] is a weed primarily of riparian areas. It is found in every state of Australia and the Northern Territory. In NSW it is predominantly found along the central and northern coast. In the Hunter Valley of NSW Giant reed is prevalent along several major waterways. These include the Pages, Paterson, Allyn, Williams and the Hunter River.

Giant reed is a bamboo like plant that can grow up to 10 m tall. It has hollow woody canes that support blue / green leaves that attach to the stem by a sheath wrapping around the stem. It produces a tall plume like flower head, up to 60 cm, which produce seeds. However, in many cases, including in the Hunter Valley these seeds are unviable. The Hunter population has been studied and it has been determined this population are sterile clones (Haddadchi & Gross). The plant reproduces vegetatively from spreading rhizomes or from fragments of rhizomes that break off and establish at new locations. Fragments of fresh stems can produce roots from the nodes if in contact with soil.

Giant reed forms impenetrable thickets (several hundred stems per square metre), creating a monoculture, where no other vegetation can establish or persist, native or exotic species included. If left unabated these thickets can spread along entire reaches of a river. Although they provide protection for riverbanks, they can also cause large sections to break away because their root systems, although dense, will only grow to a depth of up to one metre. This means the root system can be undercut and easily dislodge large sections of riverbank. This dislodged giant reed then causes further issues downstream as a flood rack of vegetation, which can cause significant infrastructure and riparian damage. The mobilised giant reed will eventually lodge on a riverbank or bed, where it will set root and establish as a new giant reed colony. Giant reed can block or significantly alter the course of a river.

Note that giant reed can also establish in areas away from riparian areas and has been seen establishing on soil and gravel stock piles and along areas where roadworks have been undertaken. These most likely have established from plant matter that has been transported in these materials, or possibly on machinery associated with these activities.

Other issues that giant reed presents include its high water use. It can use up to 2000 L m⁻² (Csurhes 2009), significantly higher than that of native riparian vegetation. Evidence also shows that giant reed has no habitat or feed value to native fauna. In fact, the plant has toxins in it which make it unpalatable to native fauna and is also suspected of releasing toxins into the water, which deters other plants while favouring its own growth (Bell 1997, Dudley 1998, CRC 2005)

The advance of giant reed along our waterways is having a significant detrimental impact on their function. One of the main reasons it has been able to establish so extensively has been due to the time consuming and costly control of traditional methods. Traditional methods of control are varied, with different rates of success. The more proven methods such as cut and paint, although generally effective is very labour intensive and hence costly. Other methods such as root removal by mechanical means is costly and causes a high amount of ground disturbance, which is not desirable, particularly in riparian areas. Foliar spraying is a quicker and more cost effective method, however the ability to get the coverage required is impeded by the sheer size and density of most thickets.

In all these cases as with most weed control follow up is required as giant reed has a high resilience due to its extensive root mass. Therefore, in most cases the use of a variety of control methods is required.

METHODOLOGY

Aim

Looking at the growth habit of giant reed and the costly nature of current methods an alternative treatment method is needed if we are going to make significant process with its management. We need to stem the tide of the advancing giant reed if we don't want to lose our rivers to it.

This trial aims to provide a comprehensively effective treatment and significantly reduce the cost associated with controlling giant reed. The trial was commenced in Autumn 2016 and is ongoing at the time of writing.

The trial is a collaboration between the private and public sector, Sky Land Management Pty Ltd and NSW DPI Tocal College respectively. Further trial work has also begun with Hunter Local Land Services too.

Treatments

The trial proposes a combination of control methods, based on the stage in the control timeline as well as the location of the giant reed on the riverbank. The giant reed at the trial site stretches from the water edge up onto the flood plain, on the Paterson River at Tocal, NSW.

To overcome the difficulty in accessing the giant reed an Unmanned Aerial Vehicle (UAV) has been used to apply herbicide as the primary treatment. The aircraft used is a Yamaha Rmax rotary wing UAV. The Rmax UAV presents several advantages over traditional methods in the treatment of giant reed. Firstly, the aircraft efficiently accesses the entire thicket. Secondly, the rotor wash created by the UAV accurately pushes the herbicide through the entire stratum of the giant reed.

The trial site has been broken into six adjacent sections, each of which have received different herbicide treatments.

The herbicide used is glyphosate 360g L-1 (Roundup Biactive®) and glyphosate 570g L-1 (Roundup UltraMax®), both with and without an acidifier (LI 700). The initial application was done in Autumn 2016 on four of the six plots only, using a low rate, then followed up with treatment of all six sites at a higher rate as outlined in the table below.

Table 1. Herbicide treatments

Plot	Herbicides	Autumn 2016 - rate	Spring 2016 -rate
1b	Glyphosate 360g L ⁻¹ (Roundup Biactive)	2%	20%
1ba	Glyphosate 360g L ⁻¹ (Roundup Biactive)	2% + acidifier (LI 700)	20%
2u	Glyphosate 570g L ⁻¹ (Roundup UltraMax)	1.4%	13.33%
2ua	Glyphosate 570g L ⁻¹ (Roundup UltraMax)	1.4% + acidifier (LI 700)	13.33%
3b	Glyphosate 360g L ⁻¹ (Roundup Biactive)	No treatment	20%
3u	Glyphosate 570g L ⁻¹ (Roundup UltraMax)	No treatment	13.33%

The next stage is to burn the plots to remove the significant biomass. The burn was initially scheduled for autumn 2017 however circumstances have delayed this to late winter (still to be conducted at time of writing).

Once the burn is complete it is anticipated that there will be regrowth, which will then be retreated with the higher rate of herbicide, in spring 2017. This application will be done using the UAV, once the canes have reach approximately one meter tall. It is anticipated that a follow up spray or at least cut and paint treatment of any surviving stems after this treatment will be required.

Once the giant reed is mostly under control the site will be revegetated through aerial seeding using the UAV. The seed mix will include a sterile cover crop and suitable native riparian vegetation for the site.

Note that a buffer strip along the water edge was not treated, to provide some stability to the river bank. Once vegetation is well established behind this narrow strip of giant reed, it can be manually removed using cut and paint methods.

RESULTS

While it is early days for this trial, the results to date are quite successful. One of the benefits anticipated from using the UAV was its ability to force the herbicide through the full stratum of the giant reed. To establish if this was achieved water sensitive paper was placed from ground level up to 2400mm off the ground. All paper had droplets on them, with decreasing coverage closer to the ground but the one on the ground had some minor cover too. This showed that the herbicide was getting right through the plant profile.

Autumn 2016

The autumn treatment at the lower rate resulted in a kill rate of 80-90% of the thickets. It resulted in no new shoots in the following spring, as was evident in the non-treated adjacent giant reed. It was noted regrowth showed signs of the effects of herbicide (stunted, yellowed margins) on existing canes, as shown in Figure 1 and was generally only found less than half way up the canes, with the top half of the canes observed as dead.

The effect of the acidifier added was indistinguishable to the plots which did not have it added within each herbicide type, and hence it was decided that this would not be used in the next herbicide treatment. The lower concentration Glyphosate 360g L⁻¹ was slower acting than the glyphosate 570g L⁻¹ however the result was the same. The 360 formulation achieved the 80-90% mortality at 12-14 weeks, whereas the 570 formulation achieved the same milestone at 8-10 weeks.



Figure 1. Herbicide affected regrowth, spring 2016

Spring 2016

The second herbicide application using the UAV in the following spring was done over all six plots. This included the primary treatment of plots 3b & 3u and secondary treatment of plots 1b, 1ba, 2u, 2ua. Using the higher rate (maximum allowable under the label) on plots 3b and 3u provided the opportunity to evaluate the effectiveness of a single application at the higher rate.

This single application had a significant result with plot 3u achieving close to 100% mortality within 6 weeks and plot 3b achieving the same result in 8-10 weeks.

The four plots previously treated in autumn showed further decline resulting from the secondary application. A further 50% of the live giant reed was killed with this second treatment. This result was not as successful as desired. The reason for this result may be due to the fact that these plants were still showing signs of the impacts from the previous treatment and therefore were less receptive to this treatment.

CONCLUSION

Based on the results to date, the recommended application rate of herbicide using this application method is the higher rate. That is glyphosate 360g L⁻¹ at the rate of 20% and glyphosate 570g L⁻¹ at 13-14% as these rates achieved the best result with a single treatment and has left the giant reed in a suitable state to burn.

Giant reed has an extensive root mass and is a large plant. The key is to get sufficient volume of herbicide onto the plant, which the UAV was able to achieve, and to give it sufficient time to work right through the plant. Although the 570 formulation worked quicker, the 360 formulation provided almost the same result after a longer time.

As giant reed tends to grow adjacent to or in waterways the only option is to use a herbicide such as the 360 formulation (Roundup Biactive[®]), which is permitted for use in aquatic zones.

This trial still has some time to run however the use of the Unmanned Aerial Vehicle (UAV) has proven effective and efficient in the application of herbicide on giant reed. The ability to get over the entire thicket and achieve the necessary herbicide coverage has resulted in a significant time and cost saving as well as having zero impact on the ground. This also applies to other weeds that would otherwise be difficult to access or to gain full coverage using ground based methods.

REFERENCES

Azadeh Haddadachi and C.L. Gross *An Assessment of the Mechanisms of Seed Infertility in Giant Reed: Arundo donax* L.(Poaceae). Ecosystem Management. University of New England.

Bell, G.P. (1997) Ecology and management of *Arundo donax*, and approaches to riparian habitat restoration in Southern California. In Brock, J. H., Wade, M., Pysek, P., and Green, D. (Eds.): *Plant Invasions: Studies from North America and Europe*. Blackhuys Publishers, Leiden, The Netherlands.

Csurhes, S. (2009) *Giant Reed Arundo donax – Weed Risk Assessment*. Queensland Primary Industries & Fisheries

Dudley, T.L. (1998). *Arundo donax*. In C. Bossard, J. Randall, and M. Hoshovsky, (Eds.): *Noxious Wildland Weeds of California*.

CRC for Australian Weed Management (2005) *Press Release, 28 December 2005. Giant Musical Reed Threatens Yarra, Torrens*.

Hunter Local Land Services (2017) *Managing Giant Reed (Arundo donax)*. State of NSW through Local Land Services

DEVELOPING A PORTABLE DNA-BASED PLATFORM FOR RAPID ON-SITE IDENTIFICATION OF CHILEAN NEEDLE GRASS AND SERRATED TUSSOCK

LAMP diagnostics of invasive stipoid grasses

David Gopurenko^{1,4}, Aisuo Wang^{2,4} and Hanwen Wu^{3,4}

¹ Research Scientist, Wagga Wagga Agricultural Institute, New South Wales Department of Primary Industries, Pine Gully Road, Wagga Wagga, NSW 2650.

Email: david.gopurenko@dpi.nsw.gov.au

² Professional Officer, Wagga Wagga Agricultural Institute, New South Wales Department of Primary Industries, Pine Gully Road, Wagga Wagga, NSW 2650.

Email: aisuo.wang@dpi.nsw.gov.au

³ Principal Research Scientist, Wagga Wagga Agricultural Institute, New South Wales Department of Primary Industries, Pine Gully Road, Wagga Wagga, NSW 2650.

Email: hanwen.wu@dpi.nsw.gov.au

⁴ Graham Centre for Agricultural Innovation (An alliance between NSW Department of Primary Industries and Charles Sturt University), Locked Bag 588, Wagga Wagga, NSW 2678

SUMMARY Weeds of National Significance (WoNS) such as Chilean needle grass (*Nassella neesiana*) and serrated tussock (*Nassella trichotoma*) can often only be distinguished from native grasses at later flowering stages. As a result, weed surveillance field officers may not recognise new emergences of these WoNS until after they have established as difficult to control populations.

Laboratory based genetic diagnostics allow an alternative means of identifying weeds, but require the use of complex procedures and equipment operated by specialist technicians. In contrast, the development of a simple low cost genetic platform which could be used in the field by non-specialists to rapidly identify suspected weeds remains a challenge. Genetic diagnostics using loop-mediated isothermal amplification (LAMP) can be done within an hour and is currently used as a simple non-specialist method for rapidly identifying various pathogens. We propose LAMP diagnostics could similarly be developed for field identification of targeted weeds.

Here we discuss the early stages required for the development of a portable LAMP platform targeted for use by field officers to allow early detection of Chilean needle grass and serrated tussock. Delivery of a successful platform would minimise the time-lag to initial recognition of emergence of these weeds in novel areas outside of their established ranges, improving time to management response for local eradication of the weeds.

Keywords: WoNS, *Nassella neesiana*, *Nassella trichotoma*, genetic

INTRODUCTION

The negative impacts of established invasive weeds on Australia's natural and agricultural ecosystems are well documented. Australian biosecurity and weed control agencies stress the importance of bio-surveillance and early detection in efforts to limit further spread of high impact weeds to new areas outside of their established range. The earlier an emergent weed is detected, the more likely its abatement can be ensured, and this is preferable to the costly alternative of ongoing control of a permanent established weed. Chilean needle grass (*Nassella neesiana* [Trin. & Rupr.] Barkworth) and serrated tussock (*N. trichotoma* [Nees] Hack. ex Arechav.) are two South American stipoid grasses that entered Australia during the early 20th century. Their status in Australia as Weeds of National Significance (WoNS) requiring co-ordinated national approaches to control their spread and reduce their impact on natural and agricultural ecosystems is well warranted (McLaren et al., 2002). Their negative impacts on agricultural and natural grassland ecosystems are profound. Where established, these weeds cause economic losses to pastoral land and grazing livestock industries (CRC, 2003a & b) and they outcompete endemic grass species leading to the extirpation of native grass bio-communities (Iaconis, 2004). Both weeds are established in substantial portions of temperate south-eastern Australia, and if unabated are likely to expand their established ranges due to their high dispersal potential coupled with their soil seed bank longevity. These weeds provide little or no nourishment to livestock, but impose high control costs so as to contain their established populations. Early intervention to eradicate novel emergences of these weeds, preventing their ability to establish in new locations, is preferable to the costly alternative of perpetual control once established. Rapid identification of emergent weeds in the field is however often problematic. In the case of the invasive *Nassella* grasses, they can be difficult to distinguish from native species at early stages of development. Descriptive morphological keys for their identification are generally useful at later flowering stages, by which time the species are likely to have increased seed set within an area. As a result, field officers involved in weed surveillance for *Nassella* weeds may not recognise new emergences of the weeds until after they have established as a difficult to control populations.

THE PROMISE OF IN-FIELD GENETIC DIAGNOSTICS OF WEEDS

Laboratory based genetic diagnostics provide the reality of an alternative means to identify weeds (Gaskin et al., 2011). Genetic methods for identification of weeds typically require serial laboratory treatments and analyses (Gopurenko et al., 2014), and are generally not conducive for use by non-specialists under field conditions. Development of simple low cost genetic methods used in the field by non-specialists to rapidly ascertain the presence of focal weeds remains a challenge. The promise of in-field genetic diagnostics has received much focus in pathogen research, where rapid diagnostics are essential in the containment of emergent pathogens across host populations. Loop-mediated isothermal amplification (LAMP; Notomi et al., 2000) has been frequently advocated for use in pathogen field diagnostics, because of its increased sensitivity, specificity and portability over conventional PCR-based approaches (Parida et al., 2008). LAMP has also been developed for improved detection of genetically modified crop plants (Lee et al. 2009;

Guan et al. 2010; Huang et al., 2014), and infrequently for pest arthropod diagnostics (Adachi et al., 2010; Przybylska et al., 2015). There are currently (as of June 2017) no reported direct uses of LAMP for weed diagnostics.

We believe a LAMP platform could be developed specifically for diagnostics of Chilean needle grass and serrated tussock and used for rapid identification of these weeds in the field. Nucleotide sites unique to each of these two weed species identified by our earlier DNA barcode research (Wang et al., 2014; 2016; 2017) could be targeted for LAMP development to distinguish the targeted *Nassella* weeds from other grass species in Australia. Further, we propose the simplicity of the LAMP method allows it to be potentially developed as a mobile assay platform suitable for rapid and targeted weed species diagnostics by non-specialist field officers. We are currently engaged in a two-year research project to develop the proposed platform, funded through the Agricultural Competitiveness White Paper (Commonwealth of Australia, 2015) *Control Tools and Technologies for Established Pest Animals and Weeds Programme*. The development and proofing stages required for the delivery of our proposed LAMP platform are described in detail in the following paper.

LAMP DIAGNOSTICS: ADVANTAGES AND EMPIRICAL ISSUES

DNA based diagnostics of pathogens, pests and weeds generally rely on conventional techniques such as Polymerase Chain Reaction (PCR) for amplification of informative target nucleotide regions (loci) used in downstream genetic analyses (Gaskin et al., 2011). Multi-step thermal cycling is critical for PCR amplification and this places logistical limits on its application for in-field diagnostics. In contrast, LAMP is not reliant on complex thermal cycling and can replicate large quantities of linked and alternatively inverted copies of a target DNA from low titre templates (Notomi et al., 2000). The method uses a single-temperature for auto-cycling of DNA strand-displacing polymerase activity in the presence of a suite of primers to induce synthesis and logarithmic replication of stem-loop bounded and linked copies of a target locus. Accordingly LAMP is highly efficient at replicating substantial quantities of a target DNA as a complex which can be rapidly visualised using simple methods (Mori et al., 2001). The significance of these features of LAMP for improved simplified genetic diagnostics under both laboratory and (in particular) field conditions has been advocated elsewhere (Parida et al., 2008; Tomlinson et al., 2010a).

LAMP essentially provides a test for the presence / absence of a target organism, using primers optimised for recognition of nucleotide sites specific to the target. For the purposes of our genetic diagnostics of the *Nassella* weeds, the 1st phase of our project will require extensive LAMP development and proofing of primer suites, to determine their efficiency for universal amplification of the target population exclusive of all other organisms. Prior research indicates that redundancy observed in the primer suite development phase can be expected (Parida et al., 2008) and therefore replicated testing of primer suites for each locus using known positive and negative targets will be required. Our previous DNA barcode analyses of native and invasive stipoid grasses in eastern Australia (Wang et al.,

2014; 2016; 2017) identified several nuclear and chloroplast DNA loci that are likely to be useful as targets for LAMP diagnostics of the focal *Nassella* weeds. In particular, nuclear ribosomal gene targets such as the external transcribed spacer (*ETS*) and internal transcribed spacer (*ITS*) regions each contain nucleotide sites that are unique to each of the two focal weeds and potentially of use for LAMP diagnostics. Chloroplast DNA loci, though potentially useful for separating *Nassella* species from other grasses, have limited utility for separating various species in the genus (Wang et al., 2017). Therefore, our immediate research will preferentially focus on development and ascertainment of the *ETS* and *ITS* nuclear loci under laboratory conditions. Issues affecting the utility of these two nuclear loci for DNA barcoding of grasses, including amplification of fungal contaminants using *ITS* primers and failure of *ETS* primers to amplify across ~ 50% of assayed grass species (Wang et al., 2017) are unlikely to affect our LAMP development phase. This is because the primer suites used in LAMP will be designed for high – specificity to a restrictive taxonomic group (i.e. the two *Nassella* species), as opposed to universal amplification of a broader taxonomic group (e.g. all stipoid grass species) as is required in DNA barcoding campaigns. Furthermore, the smaller target region size generally assayed in LAMP (< 150 bp) is less likely to be affected by issues such as DNA degradation affecting PCR amplification of larger > 500bp regions typically required for establishing DNA barcodes libraries of a particular taxonomic groups (Gopurenko et al., 2013).

The ability to simultaneously include test controls for deployable LAMP is also a major consideration for platform design (Tomlinson et al., 2010a). Unambiguous interpretation of LAMP tests for the presence/absence of a target organism critically requires a means to determine causality of negative test outcomes. Such outcomes can occur either by absence of the target organism in the assay or by empirical failure of the test itself (due to corruption of the procedure). For our purposes, we will need to incorporate a simultaneous positive control for generic plant presence in our LAMP tests. By so doing, a negative result observed at the control would indicate failure of the test procedure as opposed to absence of the target *Nassella* species in the plant assay. Amplification interference induced by multiplexing several primer suites targeted to independent target and control loci can potentially confound simultaneous LAMP testing (Tomlinson et al., 2010b). Replicate testing at the development phase is therefore critically required to ensure simultaneous LAMP assays of the control and target loci are not confounded by multiplexing for multi-locus targeting. Another consideration concerns test contamination. The sensitivity of LAMP to low titre target DNA, coupled with its capacity to produce 10-fold increases in amplified products compared to conventional PCR (Mori et al., 2001), increases its susceptibility to target DNA contamination and false-positive test outcomes. The high standards of contamination risk reduction employed in PCR methodology to ensure false-positive test outcomes are minimised, are essential in LAMP development and for its deployment as an in-field diagnostic (Tomlinson et al., 2010b).

Considerations for in-field testing of the LAMP procedure will significantly affect our ultimate LAMP platform design. Major issues to be addressed in the second phase of our project concern the levels of specimen preparation needed to release DNA for LAMP

testing, development of minimal handling procedures to reduce contamination, and provision of an efficient and cost-effective method for visualising test outcomes. We are, however, encouraged by in-field integrated LAMP procedures reported elsewhere to overcome such issues. In particular, the use of disposable lateral-flow devices incorporating nitrocellulose membranes containing immunoassay strips specific to control and target LAMP products is one such approach in obtaining a fast and cost effective LAMP assay (Tomlinson et al., 2010a & b). Other integrated LAMP amplification/detection approaches, such as those incorporating integrated micro-fluidic technology (Myers et al., 2013) implemented into portable devices will also be considered.

CONCLUSIONS AND PROSPECTS

To successfully develop LAMP diagnostics of Chilean needle grass and serrated tussock we will need to overcome many hurdles to ensure target specificity and detection reliability. In addition, transfer of this technology from a laboratory based platform to one which has in-field portability will present new challenges involving ease of use/interpretation and ultimately its cost-effectiveness. Successfully meeting these challenges will allow adoption of the platform for its primary purpose here, and potentially for other weed diagnostics. We envisage the immediate beneficiaries of this LAMP diagnostic platform will be for front-line weeds surveillance officers and related biosecurity or community service groups, who will have increased on-site capacity to correctly and rapidly identify Chilean needle grass and serrated tussock. Managers of surveillance groups will benefit from the increased speed at which reliable surveillance data could be delivered by on-site staff using the platform. For example, the suspected emergence of a weed reported across new locations could be rapidly tested using the platform, allowing managers earlier informed capacity to decide on the appropriate scale of control measures and response actions required to abate further spread of the weed. Broader adoption of the LAMP platform for other weed diagnostics is foreseeable. For example, the LAMP platform could be specifically modified to detect other focal weeds. For such purposes, diagnostic LAMP primers for a particular weed would need to be developed. DNA barcode campaigns which report nucleotide sequences for species identification of various taxa (Hebert et al., 2003) ultimately can provide much of the raw genetic data essential for LAMP primer development. Sequences available at online sequence repositories such as BOLD and GenBank of taxonomically curated species are therefore critical to the initial phases of LAMP primer proofing to determine target ubiquity. Finally, we envisage use of LAMP platforms for detection of weed and or bacterial contaminations in transported agricultural produce, thereby adding assurance to the "Green and Clean" status of Australian products and improving opportunities for domestic and overseas market access.

ACKNOWLEDGMENTS

Funding support for this project (CT-17) is provided through the Agricultural Competitiveness White Paper (Commonwealth of Australia, 2015) *Control Tools and Technologies for Established Pest Animals and Weeds Programme* administered by the Department of Agriculture and Water Resources. We acknowledge edits provided by Gretchen Kay Foster and anonymous reviewers to improve our manuscript.

REFERENCES

- Adachi, T., Umezawa, T., Yamaguchi, H., Kitamura, T., Honda, K., Shibao, M., Nasu, Y., and Tanaka, H. (2010). Identification of *Bemisia tabaci* B and Q biotypes in Osaka Prefecture by DNA sequencing and a LAMP method. *Annual Report of the Kansai Plant Protection Society* 52, 103–104.
- Commonwealth of Australia. (2015). Agricultural Competitiveness White Paper, Canberra
- CRC for Australian Weed Management (2003a). Chilean needle grass (*Nassella neesiana*) weed management guide. Weeds of National Significance. Department of the Environment and Heritage and CRC for Australian Weed Management. ISBN 1 9209 3205 4
- CRC for Australian Weed Management (2003b). Serrated tussock (*Nassella trichotoma*) weed management guide. Weeds of National Significance. Department of the Environment and Heritage and CRC for Australian Weed Management. ISBN 1-920932-17-8
- Gaskin, J., Bon, M.C., Cock, M., Cristofaro, M., De Biaes, A., De Clerck-Floate, R., Ellison, C., Hinz, H., Hufbauer, R., Julien, M. and Sforza, R. (2011). Applying molecular-based approaches to classical biological control of weeds. *Biological Control* 58(1), 1-21.
- Gopurenko, D., Fletcher, M.J., Löcker, H. and Mitchell, A. (2013). Morphological and DNA barcode species identifications of leafhoppers, planthoppers and treehoppers (Hemiptera: Auchenorrhyncha) at Barrow Island. In 'Records of the Western Australian Museum, Supplement 83: The Terrestrial Invertebrate Fauna of Barrow Island', eds. N.R. Gunawardene, J.D. Majer, C.K. Taylor & M.S. Harvey. (Western Australian Museum Publications, Perth). pp. 253–285.
- Gopurenko, D., Wang, A., Zhu, X., Lepschi, B.J. and Wu, H. (2014). Origins and diversity of exotic silverleaf nightshade (*Solanum elaeagnifolium* Cav.) present in Australia as determined by sequence analysis of a chloroplast DNA intergenic spacer region. Proceedings of the 19th Australasian Weeds Conference – Science, Community and Food Security: the Weed Challenge, 1–4 September, Hobart, Tasmania, ed. M. Baker. (Tasmanian Weed Society, Hobart). pp 392-395.
- Guan, X., Guo, J., Shen, P., Yang, L. and Zhang, D. (2010) Visual and rapid detection of two genetically modified soybean events using loop-mediated isothermal amplification method. *Food Analytical Methods* 3(4), 313-320.

- Hebert, P.D.N., Cywinska, A., Ball, S.L. and deWaard, J.R. (2003). Biological identifications through DNA barcodes. *Proceedings of the Royal Society of London. Series B. Biological Sciences* 270(1512), 313–321.
- Huang, X., Chen, L., Xu, J., Ji, H-F., Zhu, S. and Chen, H. (2014). Rapid visual detection of phytase gene in genetically modified maize using loop-mediated isothermal amplification method. *Food Chemistry* 156(1), 184–189.
- Iaconis, L. (2004). How is the national Chilean needle grass program progressing? Proceedings of the 14th Australian Weeds Conference, eds. B.M. Sindel and S.B. Johnson. (Weed Society of New South Wales: Sydney). pp. 636–639.
- Lee, D., La Mura, M., Allnutt, T.R. and Powell, W. (2009). Detection of genetically modified organisms (GMOs) using isothermal amplification of target DNA sequences. *BMC Biotechnology* 9(1).
- McLaren, D.A., Coventry, R. and Thorp, J. (2002). Stipoid grasses as Weeds of National Significance. *Plant Protection Quarterly* 7 (3), 119–124.
- Mori, Y., Nagamine, K., Tomita, N. and Notomi, T. (2001). Detection of loop-mediated isothermal amplification reaction by turbidity derived from magnesium pyrophosphate formation. *Biochemical and Biophysical Research Communications* 289(1), 150–154.
- Myers, F.B.1., Henrikson, R.H., Bone, J.M. and Lee, L.P. (2013). A handheld point-of-care genomic diagnostic system. *PLoS One* 8(8), e70266.
- Notomi, T., Okayama, H., Masubuchi, H., Yonekawa, T., Watanabe, K., Amino, N. and Hase, T. (2000). Loop-mediated isothermal amplification of DNA. *Nucleic Acids Research* 28(12), e63.
- Parida, M., Sannarangaiah, S., Dash, P.K., Rao, P.V.L. and Morita, K. (2008). Loop mediated isothermal amplification (LAMP): a new generation of innovative gene amplification technique; perspectives in clinical diagnosis of infectious diseases. *Reviews in Medical Virology* 18(6), 407– 421.
- Przybylska, A., Fiedler, Ż., Kucharczyk, H. and Obrępańska-Stęplowska, A. (2015). Detection of the quarantine species *Thrips palmi* by Loop-Mediated Isothermal Amplification. *PLoS ONE* 10(3), e0122033.
- Tomlinson, J.A., Boonham, N. and Dickinson, M. (2010a). Development and evaluation of a one-hour DNA extraction and loop-mediated isothermal amplification assay for rapid detection of phytoplasmas. *Plant Pathology* 59(3), 465–471.
- Tomlinson, J.A., Dickinson, M.J. and Boonham, N. (2010b). Rapid detection of *Phytophthora ramorum* and *P. kernoviae* by two-minute DNA extraction followed by isothermal amplification and amplicon detection by generic lateral flow device. *Phytopathology* 100(2), 143–149.
- Wang, A., Gopurenko, D., Wu, H., Stanton, R. and Lepschi, B.J. (2014). DNA barcoding for identification of exotic grass species present in eastern Australia. Proceedings of the 19th Australasian Weeds Conference – Science, Community and Food Security: The Weed Challenge, 1–4 September, Hobart, Tasmania, ed. M. Baker. (Tasmanian Weed Society, Hobart). pp 444-447.
- Wang, A., Wu, H. and Gopurenko, D. (2016). Chloroplast genome of the serrated tussock (*Nassella trichotoma*): Structure and evolution. Proceedings of the Twentieth Australasian Weeds Conference, 11-15 September 2016, Perth Western Australia, eds R. Randall, S. Lloyd and C. Borgner, (Weeds Society of Western Australia). pp 152-156.
- Wang, A., Gopurenko, D., Wu, H. and Lepschi, B. (2017). Evaluation of six candidate DNA barcode loci for identification of five important invasive grasses in eastern Australia. *PLoS ONE* 12(4): e0175338.

GREATER SAFETY AND EFFICIENCY THROUGH USE OF IMPROVED REMOTE REWIND HOSE REELS

Daniel Firth

D & G Firth Pty Singleton NSW

Email: dgf@exemail.com.au

SUMMARY While remote rewind hose reels can be used for many different applications, this paper embraces their use for pesticide and weed spraying. These reels may also be referred to as Auto Reels, or Radio Controlled Hose Reels however they all are designed to perform the same task of; enabling an operator to single-handedly rewind a hose of considerable length while remotely located from that reel, allowing them to be safer and more efficient.

There remains little doubt as to the known improved efficiency gained through use of auto reels in Australia with their adoption being relatively high compared to most other countries.

The greatest opportunities for improvements lie within the increase in safety and ease of use for both experienced operators and new adopters alike. This second category of users is rising rapidly due to the increase in affordability and the reduction in size of units that are now auto reel equipped.

Keywords: Auto Reel, Remote Controlled Hose Reel, Buddy Smart Reel™

INTRODUCTION

The original remote controlled reel in Australia was invented by experienced weed-spraying contractor Adrian Anderson of Uralla NSW and was patented in Australia in 1991 with the applicant company's address being, Beardy Street Armidale NSW.

The first auto reels were powered by indirect mechanical means from the internal combustion engine (**ICE**) that powers the spray pump. This involved various reduction mechanisms and an electromagnetic clutch to engage rotation when the hand held remote radio transmitter was operated.

These reels introduced the concept of using semi-rigid nylon, single extrusion tubing, as the fluid hose. The use of this type of hose eliminated the need of any form of mechanical layering mechanism as it was harder, smoother and had greater lubricity than the more common flexible PVC or rubber spray hoses. These properties allowed the hose to layup in a random form without stacking too high. Complementing this attribute was the adoption of a spool with a narrower width than traditional forms, but of greater diameter. Addition benefits of the nylon hose, was its greater resistance to kinking, smaller outside diameter and the reduced friction against the ground. The friction advantage was of importance as these mechanical reels required some extra pull force to overcome the inherent resistance in the reel speed reduction mechanism as well as the fact that they could contain much longer hoses than most manual reels.

As the concept gained ground, a derivative that was driven from a 12volt electric motor via a reduction gearbox and V belt drive emerged, eliminating the need of the magnetic clutch as the motor could be started and stopped directly from the radio remote.

Auto reels in the early days were mostly embraced by government departments and weed spraying contractors who could envisage the time and labour savings of the new technology in addition to having access to budgets that allowed them make the significant investment required.

Following the lapse of the original patent, we saw a steady increase in the manufacturers of auto reels, each with their minor changes but still essentially the same in operation as the original mechanical or 12 Volt driven units.

As expected the entry of more players in the auto reel space did lead to some increase in affordability but their use was still prohibitive for users who were not able to invest in larger equipment due to its cost, or the cost of the vehicle required to carry it.

At AgQuip™ in August 2014 Rapid Spray, an already well established sprayer manufacturer, exhibited an auto reel that delivered the already known advantages of remote controlled reels, plus many new and previously unavailable features at a price and physical size never seen before.

The Buddy Reel™ as it was aptly named, was 36% lighter and occupied 48% less space than its nearest competitors allowing auto reels to be used on vehicles as small as quads and UTV's. This major progression has put auto reels into the hands of so many more operators than ever before. Not only was it compact, but in addition the Buddy's internationally patented technology made it the most user-friendly auto reel available and requiring considerably less maintenance than other auto reels.

In March 2017, Rapid Spray passed another milestone with the release of the further featured Buddy Smart Reel™. This advanced unit, maintained the already known advantages of the original Buddy Reel™, while adding many more user friendly and improved safety features as well. At the same time the Buddy Smart Reel™ range was extended to include still compact but full sized 100, and 150 m long hose capacities.

MATERIALS AND METHODS

Auto reels can be broken down into 3 main types, Mechanical Auto (**MA**), Belt or Chain Driven Electric (BDE) and Direct Drive Electric (DDE).

MA reels are powered by mechanical means from the small ICE that powers the spray pump. This involves various reduction mechanisms, chains or rubber belts and an electromagnetic clutch to engage rotation to the reel spool when the hand held remote radio transmitter is operated. These reels also require an electric source, usually 12 VDC, to energise the electromechanical clutch.

BDE auto reels are powered by 12 or 24 VDC electric power source that may originate from the charging system of the spray pump's ICE electric starting system, or from an independent source like that of a common motor vehicle battery. The electric motor is usually connected to a reduction gearbox which is in turn linked to the reel spool via either a rubber belt and pulleys, or a chain and sprockets.

DDE reels are powered from similar sources as BDE reels, but eliminate the need of separate belts or chains by attaching the motor, and reduction transmission if required, directly to or even inside the spool.

MA reels can transfer quite large amounts of torque from the ICE to the reel spool but are limited in the ability to adequately control this transmission. By nature, the use of an electromagnetic clutch to engage a stationary reel spool to a constantly rotating drive axle, produces an abrupt result, and once the spool is rotating, and the hose rewinding, its speed can only be controlled through variation in the driving ICE's revolutions. When most electro clutches are engaged, there is little method of limiting the torque of the spool and hence the linear pull on the attached hose. This ability to apply large amounts of uncontrolled torque has resulted in incidences of operator injury under some circumstances. Torque limiting on Mech. reels is often attempted by either loosening drive belt tension and allowing slippage to occur, or reduction in spring pressure in the clutch, allowing it to slip. Both methods, being mechanical, create increased wear and tear increasing maintenance costs, and are subject to potential abuse by operators wishing to use the hose as a human winch.

Both BDE and DDE reels employ an electric motor that can be more accurately controlled than their MA counterpart. Unfortunately, few manufacturers take advantage of this feature, and choose to continue using outdated electro-mechanical relay technology. The absence of speed control on most electric reel motors puts them in a worse position than MA reels as their revolutions cannot be altered.

Most fixed speed BDE and DDE reels are torque limited by the addition of a simple overcurrent device. Whilst it is possible to employ a resettable circuit breaker to prevent overcurrent, and therefore limit torque, most manufacturers still use a consumable automotive fuse. The replacement of this fuse, or the resetting of the circuit breaker, if activated due to a snag on the hose requires the operator to return to the reel from their working position, wasting valuable time and energy. When replacing this fuse, it is possible for the operator to substitute it with one of a higher current rating leading to possible total motor burnout.

Most electrically driven reels contain a permanent magnet internally commutated direct current electric motor. These devices employ a rotating commutator with carbon brushes (usually a set of 2) to provide opposing magnetic forces that cause the output shaft to rotate. These carbon brushes are in fact a consumable item designed to wear away through normal use and eventually be replaced. While not always visible they will cause sparking, much the same as what can be observed in the rear of many hand-held drills, and could present a fire hazard especially in the presence of petrol used in most ICEs should it be

spilled during refuelling. The carbon brushes are held in contact with the commutator using small, springs usually of coil form. Failure of these springs due to corrosion is commonly documented, this can lead to complete motor failure.

The only real cure for carbon brushes is to eliminate them altogether and this has been made possible through advancement in what are known as Brushless Direct Current (BLDC) Motors. This class of motors, as their name indicates, contain no carbon brushes at all. They still contain powerful permanent magnets but the generation of the opposing magnetic forces to cause the rotation is achieved electronically as opposed to mechanically. This method necessitates the use of a dedicated electronic controller; however, the same controller also makes motor speed and torque control much easier. BLDC motors are more efficient, draw less current as well as generating less heat and consequently tend to last longer than their brushed counterparts.

With modern motor control technology, it is possible to control the torque, the starting speed and operating speed, of an electrically driven hose reel. One reel that takes advantage of this technology is the Buddy Smart Reel™ that can remotely set and adjust rewind speeds while at a distance from the reel, using the hand held remote device.

As anyone who has used a remote rewind reel will appreciate, when operating over varying terrain you may wish to change your walking pace accordingly. A MA reel will require you to continually press and release the remote with the corresponding whipping or jerking action being transferred down the hose to your hand. At the same time this stop start action is causing wear and tear to every mechanical and electrical part of the reel. A fixed speed BDE or DDE is a little less harsh but similar in result and if too much load is applied to the hose it will cause an overload situation bowing the fuse or tripping the circuit breaker along with the inherent inconveniences.

DDE reels with BLDC motors and position feedback are considerably more interactive and operator friendly. Using a combination of load sensing and stall measurement, these reels will slow down as the operator does, apply more torque to help them at their own pace, maintain maximum possible power while keeping under the pre-set tripping threshold, and only trip for equipment, and operator protection, if the reel has stalled and is not rotating. This trip can be immediately reset by releasing the remote button and pressing it again. The Buddy Smart Reel™ is the only known reel that uses this form of control.

It is an inescapable physical reality with all multi-layer hose reels that the linear hose speed will increase as the diameter of the hose layup increases while ever the reel is rotated at a constant speed. This increase is experienced by the operator to the extent that they may be required to walk, or even run, at up to twice the speed when they approach the reel, compared to how they started off with the hose fully unwound.

The solution to overcome this and maintain the hose at a constant linear speed is to gradually alter the rotation speed of the spool as the hose lays up. Such control may only be achieved through a continuous position feedback signal from the spool. It is only sufficient to have this feedback on the motor if it is directly connected to the reel as

otherwise errors will occur due to slippage in any connecting belts. To date the only auto reel to achieve this important advance is the Buddy Smart Reel™.

This hose speed increase as you rewind closer to the reel also presents another challenge whereby the operator may be dragged towards the machine at a speed and force that can cause both personal and mechanical damage. Some reel manufactures try to reduce this danger with a warning to release the transmitter button when approaching the reel, and complete the rewind by manually rotating the spool. This instruction is futile if an operator is distracted at the critical moment, or if through fatigue they release the button too late. Reels with spool position feedback such as the Buddy Smart Reel™, eliminate this dangerous situation as they can automatically slow down to a safe speed and reduced stall force when the operator is at a predetermined distance away from the reel.

While many reel companies concentrate on the amount of retraction force a reel can exert, what is possibly of greater importance, is the ease with which an operator can pull the hose of a reel out particularly considering auto reels are often considerably longer than traditional manual reels. In all cases auto reels retract the hose giving the operator some assistance, however they cannot push an operator in the opposite direction.

Due to the mechanical structure of many auto reels, pulling out the hose, first requires the overcoming of the mechanical components in place to achieve a reduction from the drive source to the reel spool. To assist in coping with this pull-out resistance some operators employ a device that fastens the hose to a belt around their waist. This is a dangerous practice that has led to accidents and injury to personnel.

The extra resistance is eliminated with DDE reels to the point that the tendency is for the spool to keep unwinding even after the operator has stopped pulling the hose out. This over running could be reduced by adding a mechanical resistance in the form of some friction as do some MA reels, however it defeats the purpose of having a free spooling reel to make the operator's task easier when pulling the hose out and could be likened to keeping the park brake of a vehicle slightly engaged all the time so it will stop when you take your foot off the accelerator. Another way to overcome this is to fit a clutch on the final drive to the spool, however this can require the operator to press a button on their remote whenever they are pulling the hose out, or as many Asian built reels do, employ a mechanical mechanism to release it. In either case, this creates another layer of mechanical complexity and added maintenance.

The alternate solution is to use smart electric braking whereby the reel automatically senses that the operator is no longer pulling the hose and applies a calculated braking force only at this point. This braking can be achieved in a BLDC motor in much the same way as is used in modern electric cars and creates a small amount of recharge to the supplying battery. The Buddy Smart Reel™ uses this system of automatic spool overrun control.

Along the drive system on a remote rewind reel, the other important area is the radio control system. This system consists of the hand-held radio transmitter, and a corresponding receiver mounted on or near the hose reel.

Surprisingly most reels still contain an added potential failure point in that they use an exposed antenna or aerial to receive the radio signal from the remote. Rapid Spray with their Buddy Smart Reel™, are the only company to date to adopt the latest advances in this field to eliminate this cumbersome component and maintenance issue, and integrate it within the main controller. The removal of this external aerial could lead to the assumption that the transmission range would be reduced, however the opposite is true with the Buddy Smart Reel™ enabling it to outperform other reels in that it has been successfully tested to between 4 and 20 times the stated line of sight range on other remote reels.

As the reel, and thus the receiver, is often exposed to the elements, it is important to ensure that this exposure does not affect the safe and efficient operation of the system so a suitable sealing method must be chosen to achieve this. This is a considerable challenge in areas of high humidity.

DISCUSSION

It is evident that while considerable scope exists, there has been a lack of adoption of many known advancements in several areas of technology by most auto hose reel manufactures. Currently it seems that there is only one truly advanced remote rewind hose reel available that improves operator safety and efficiency, as well as reducing maintenance.

REFERENCE (Not quoted – useful links)

<http://pericles.ipaustralia.gov.au/ols/auspat/applicationDetails.do?applicationNo=1991076009>

<http://www.sf-interactive.com/previewsites/quikcorp/aboutus.php>

<http://www.rapidspray.net/Sprayers/hose-reels-hose/buddy-remote-control-auto-reels>

<https://www.quikspray.com.au/>

<http://www.reeltec.com.au/pit-bull-reel/heavy-duty-remote-retractable-hose-reel/>

<http://www.goldacres.com.au/pro-reel-remote-controlled-rewind-traymount-sprayers>

Various manufactures operator handbooks

GETTING A GRIP ON THE SLIPPERY SICILIAN SEA LAVENDER *LIMONIUM HYBLAEUM*

Stephen B. Johnson

Weed Ecologist, Weeds Research Unit, New South Wales Department of Primary Industries, Locked Bag 6006, Orange, NSW 2800, Australia
stephen.johnson@dpi.nsw.gov.au

SUMMARY Sicilian sea lavender (*Limonium hyblaeum*, Plumbaginaceae) has the potential to devastate one of the most threatened Endangered Ecological Communities (EEC) in New South Wales (NSW) by area, that is coastal salt marsh (collectively covering only 7,200 ha). This “transformer” species can spread rapidly, totally excluding other plant growth, regeneration, reducing biodiversity and ecosystem function, as already evidenced in parts of the Victorian and South Australian coastline. Five years ago, around 100 m² was found at Saratoga in Brisbane Waters (south of Gosford), covering around 0.4 ha of coastal salt marsh. This paper seeks to inform all stakeholders about the threats posed by this species so as to prevent further spread.

Once sold as an ornamental species, and planted for salinity remediation purposes, this ‘cushion’ plant spreads by both seeds and rhizomes. Native to coastal Mediterranean areas (including Sicily), it is also known to have naturalised across southern Australia, including Western Australia. It is difficult to manage without off-target effects, although trials indicate that targeted thorough wetting with glyphosate and metsulfuron-methyl mixtures, combined with high rates of adjuvant, are effective. Hand weeding of small populations remains the most time- and cost-effective means of eradicating small populations.

There are a number of actions that are needed to prevent this new and emerging weed threat from slipping from our grasp and continue spreading. Some of these include: immediate surveys of all coastal salt marshes for this and other weed species; identifying and managing these and other high risk weed threats in coastal ecosystems; and removal of these plants from trade and distribution. The future spread of Sicilian sea lavender and the ecological integrity coastal salt marshes depend on the decisions we make now.

Keywords: new and emerging weed, coastal salt marsh, weed risk management assessment.

INTRODUCTION

Sicilian sea lavender (*Limonium hyblaeum* Brullo, Plumbaginaceae) is an emerging weed in southern Australia (Parsons 2013). Although not yet recognised for the threat it poses saltmarsh communities in NSW (e.g. Daly 2013), it is considered one of the three greatest weed threats to saltmarsh communities in Victoria, along with the spartina (*Spartina* spp.) and tall wheat grass (*Thinopyrum* (syn. *Lophopyrum*) *ponticum* Podp. Barkworth & D.R.Dewey) (Adair 2012).

This perennial herb or ‘cushion’ plant is a serious weed in South Australia and Victoria, has naturalised in several places in Western Australia, and, is an emerging weed threat in NSW (ALA 2017). Along with information supplied by Local Government weed officers, the NSW Government initially assessed the species in 2013 using the NSW Weed Risk Management (WRM) system (Johnson 2009a, b). This paper reviews that WRM assessment, before discussing, more broadly, the threats posed by this “transformer” species. Further, it proposes a number of management actions that are needed to prevent this new and emerging weed threat from spreading further in NSW.

BIOLOGY, INVASIVENESS and PERSISTENCE

A perennial species that only grows to ca. 250 mm high (Adair 2012, Parsons 2013, RBG&DT 2017), *L. hyblaeum* forms dense compact cushions (Rodrigo *et al.* 2012, Parsons 2013) which, once aging, degenerate from the inside (forming plant rings of increasing size) and leaving grey to white peat behind (Parsons 2013). Frequently occurring in both salt marshes and on rocky coastal sites, there are no native plants of similar habit: this unique growth form in invaded habitats help remove confusion between this weed and other native plants (including *L. australe* (R.Br.) Kuntze, native sea lavender) and exotic *Limonium* species (often grown as ornamentals, three of which have naturalised in NSW, RBG&DT 2017).

Flowers grow in aerial panicles (seed heads) composed of multiple spikelets; with each flower producing a single seed to 2 mm long (Walsh 1996, Adair 2012). Recent observations from Port Campbell (Victoria) suggest seeding occurs less than a year after plant establishment (R. Adair pers. obs.). While seed does not appear to be the primary means of reproduction, if each spikelet produced even 1 seed, well over 150 seeds would be produced per seed head (Rodrigo *et al.* 2012). This would result in well over 100 seeds m⁻² (defined as high seed production in the NSW WRM system (Johnson 2009b)). The longevity of seeds in soil and water requires further research. In contrast, vegetative reproduction in this species predominates. New rosettes are produced from rhizomes, particularly at the edge of patches (and from buds from existing patches) (Rodrigo *et al.* (2012, Parsons 2013). The number of rhizomes produced per plant as well as their longevity if excised is unclear, but requires future research.

Natural dispersal of *L. hyblaeum* is thought to occur mainly through sea (and fresh) water spread (Adair 2012). Although wind dispersal is not mentioned by Adair (2012) it is clearly suggested as a major agent by others, e.g. Parsons (2013). At best, spread by flying and other wild animals, as well as domesticated (hairy) animals would be occasional, if not uncommon (Adair 2012).

Human mediated dispersal is commonly mentioned, particularly from shoes and clothing (Adair 2012). Visitor centres, car parks and walking tracks are seen to be high risk areas of spread (Adair 2012, Rodrigo *et al.* 2012). The species is dispersed well by vehicles and soil in tyres (R. Adair pers. comm.). Accidental spread can also occur via gravel extraction, the movement of soil, and garden dumping (Adair 2012, Rodrigo *et al.* 2012). Most troubling is that the species is still likely to be sold by specialist nurseries and appears to be grown

for its flowers, and as an ornamental (Adair 2012). Information indicates that it has previously been planted for saline soil remediation purposes as well (Parsons 2013).

Plants of *L. hyblaeum* readily establish in thick salt marsh vegetation (P. Marynissen pers. obs.), as well as on rocky exposed sites. They appear to be highly tolerant to these highly saline (and often highly naturally disturbed) habitats. Routine weed management is very rarely applied to these areas: i.e. there are no incidental control checks to the spread of the species.

As an aside, this plant was designated species status (removed from a species group in 1980) by Brullo (1980, in Parsons 2013).

IMPACTS

Limonium hyblaeum severely reduces the establishment and growth of desired plants and vegetation: i.e. no seedlings of any species are found within the current infestation in a coastal salt marsh in NSW, through to the complete exclusion of the growth of all other species in Victoria (Adair 2012). Significant biodiversity impacts are already experienced in Victoria with: reductions in non-threatened biodiversity; and threats to RAMSAR wetlands, habitat for the orange-bellied parrot (*Neophema chrysogaster* Latham) - a species that is close to extinction, and saltmarsh communities, which are also already significantly threatened in NSW (e.g. Daly 2013) and Victoria.

Potential future impacts have been suggested on the protected bird species the short-tailed shearwater (*Ardenna* (syn. *Puffinus*) *tenuirostris* Temminck), in particular because the weed could inhibit burrow digging at Port Fairy (Rodorigo *et al.* 2012). Although similar impacts have not yet been formally recorded in NSW, it is likely this “transformer” species is already having analogous impacts on the affected salt marsh, one of the most threatened Endangered Ecological Communities (EEC) in the State in terms of area collectively covering only 7,200 ha, e.g. Keith (2004) and Daly 2013).

While the species does not appear to restrict human or animal movement, nor negatively affect the health of animals or people (e.g. via toxins or injury), the species impacts at least one environmental process/function, soil salinity (Adair 2012, Parsons 2013). *Limonium hyblaeum* was introduced into the Coffin Bay area in South Australia (with other *Limonium* species) to help combat soil salinity (based on herbarium records examined by Parsons (2013)). It excretes salt and has halophytic adaptations making it ideally suited to help decrease localised soil salinity issues (a positive impact from a human point of view) so that other less tolerant but ‘more desirable’ species can be grown later. Similar to other species used for salinity remediation purposes e.g. tall wheat grass *Thinopyrum ponticum*, and others (Boon *et al.* 2011, in Parsons 2013), the continued introduction of Sicilian sea lavender and analogous species for such purposes may actually result in further future impacts on naturally saline ecosystems (whether coastal or inland). It is probable that other negative effects on environmental health in salt marshes in NSW would occur, but, at this stage, require further research.

POTENTIAL AND CURRENT DISTRIBUTION IN NSW

A native species to coastal Mediterranean areas, the species is found in countries around the northern Mediterranean ocean (Spain, France, Italy (as well as Sicily and northern Sardinia)), in former Yugoslav countries, in Israel and Palestine, and in the western Black Sea (Romania and Bulgaria), and then around the western and northern Spanish coastlines, to France, Belgium, the Netherlands, Germany, Denmark, throughout England and Wales and western Ireland (Adair 2012). It occurs in basaltic soils (e.g. volcanic rock and crevices) and alkaline soils (sand and dunes) and shelly areas (Adair 2012), as well as 'in silt, sand and soil' (Rodrigo *et al.* (2012). Examining current Australian records (ALA 2017), it was assumed that all NSW salt marshes/ecosystems may be threatened (both inland and coastal) and that at least 50% of these could be potentially invaded (Johnson 2009b).

Fortunately, only one infestation is known in NSW, an area of around 100 m² spread across approximately 4,000 m² total area (half a soccer field) at Saratoga in Brisbane Waters (south of Gosford) (P. Marynissen pers. comm.). While a second record 3 km east of Lake Cargelligo in central western NSW has previously been recorded (ALA 2017), extensive investigations (field inspections and interviews with pictures provided) by Larry Clemson former Lachlan Shire Council weeds officer found no trace of this species during 2013 and early 2014. Little is known about the only other inland (semi-arid) collection from north west of Mildura in Victoria in 2017 (ALA 2017).

CONTROL COSTS AND MANAGEMENT

Salt marsh communities are generally difficult to access, both on foot, and with machinery. Having said that control of the species would likely be well within the financial and technical capabilities of those managing the weed, i.e. land holders/managers and/or volunteers. (The infestation is largely on Saratoga Island Nature Reserve which is managed by the NSW National Parks and Wildlife Service (NPWS) with adjacent patches on Local Government land managed by Central Coast Council).

Research has shown that thorough wetting with a mixture of glyphosate, metsulfuron methyl and high levels of adjuvants is 99% effective in controlling the weed (Adair 2012). This has been borne out in practice in NSW (D. Holloman pers. comm.). Small hand-spray units, or vehicle-mounted spray units (with extended hoses) would be suitable for such applications. Hand weeding of small populations remains the most time- and cost-effective means of eradicating small populations (Adair 2012, D. Holloman pers. comm.). As always, follow up control measures are recommended.

WEED RISK MANAGEMENT OUTCOMES

Using the NSW WRM system to assess *Limonium hyblaum* (Johnson 2009a, b) results in a comparative:

- weed risk score of 274 (very high); and
- feasibility of coordinated control score of 2 (very high).

with the resulting management priority category “Eradication”.

Guiding principles for management under the “Eradication” category include:

- detailed surveillance and mapping to locate all infestations, particularly in coastal salt marsh communities, given that water is a key means of natural dispersal;
- destruction of all infestations, including seed banks;
- prevention of entry into NSW, and movement and sale within;
- that the species not be grown throughout the State and that all cultivated plants be removed; and to
- monitor the progress towards eradication.

RECOMMENDATIONS FOR ERADICATION

There is a large body of knowledge that suggests that, in the weed management world, eradication is the most cost-effective response to an emerging but seriously invasive weed problem (e.g. Charlton *et al.* 2009, Auld and Johnson 2014, 2016), but that it is only feasible in the very early stages of an invasion when spread is limited (Panetta 2015, Auld and Johnson 2016). Eradication is highly feasible for *L. hyblaum* at this time.

To achieve this, many of the guiding principles outlined above, could be affected if the species was declared as Schedule 2 Prohibited matter in the Biosecurity Act 2015. (The enactment of that piece of legislation has removed previous confusion as to which legislation applied to weeds in these ‘in between’ ecosystems i.e. salt marshes that border terrestrial and saline areas with terrestrial and freshwater weeds previously dealt with under the *Noxious Weeds Act 1993* while saltwater weeds e.g. caulerpa (*Caulerpa taxifolia* (Vahl) C.Agardh) were dealt with under the *Fisheries Management Act 1994*). Until this occurs, the guiding principles outlined above should be enacted by stakeholders of the following Regional Strategic Weed Management Plans, that is for: Hunter Local Land Services (LLS), where the species is listed as a regional prevention priority (Hunter LLS 2017); and for Greater Sydney LLS where the species occurs and the species is listed as a regional eradication priority (Greater Sydney LLS 2017).

Additional recommendations include:

- a broader cross-jurisdictional survey of coastal areas identifying:
 - **new and emerging weed species** such as sea spurge (*Euphorbia paralias* L.) and marram grass (*Ammophila arenaria* (L.) Link) (e.g. Heyliers 2002, Kelly 2015, Mallick and Askey Doran 2017, RBG&DT 2017);

- new invasions of existing weeds (e.g. Daly 2013); as well as
- **assets for management from more widespread weeds** e.g. Hamilton and Turner (2013) and Scanlon (2015);
- regular monitoring of areas at high risk of invasion, including areas where visitors gather, around car parks and walking tracks, and areas where either gravel or soil are extracted, or where rubbish and waste dumping occurs; and
- protecting coastal communities from more general threats such as pollution and excessive disturbance through reclamation, engineering works, stock grazing and off-road vehicles, e.g. Daly (2017).

The future of coastal ecosystems, particularly salt marshes, and the time we have left for grabbing hold of the slippery Sicilian sea lavender as it slips out of the window of control depends on what we decide now.

ACKNOWLEDGEMENTS

I am deeply indebted to: Professor Bruce Auld, Dr Robin Adair, Mr Paul Marynissen and Mr Larry Clemson for the information and peer review they provided for the original NSW WRM assessment; to Deb Holloman, NSW NPWS for additional information on the management of the weed on Saratoga Island Nature Reserve; to Ms Jane Frances and Ms Melissa Walker, NSW DPI Aquatic Biosecurity, for general discussions and interest; and to other weed professionals in Local Government and NSW OEH who have contributed information to the NSW WRM assessment and management of Sicilian sea lavender, and for providing contacts for the same.

This paper is dedicated to the untiring efforts (as well as the friendship and support) of many NSW Local Government weeds officers who continue to make NSW a better and less weedy place.

REFERENCES

- Adair, R. (2012). Sicilian sea lavender. A new and emerging threat to Victoria's saltmarsh. <http://www.australisbiological.com.au/wp-content/uploads/2012/03/Limonium-presentation-Philip-Island-12-September-2012.pdf> (accessed 28 July 2017).
- ALA, Atlas of Living Australia. (2017). *Limonium hyblaenum*. <https://bie.ala.org.au/species/http://id.biodiversity.org.au/node/apni/2917988> (accessed 25 July 2017).
- Auld, B.A. and Johnson, S.B. (2014). Invasive alien plant management. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources 9(37). 12 pp.
- Auld, B.A. and Johnson, S.B. (2016). Impact reduction and asset protection. Proceedings of the 20th Australasian Weeds Conference, eds. R. Randall, S. Lloyd and C. Borger, pp. 78-81. (Weed Society of Western Australia, Perth).
- Charlton, S.A., Downey, P.O. and Johnson, S.B. (2009). Weed categorisation – applying the ‘PECA code’ in NSW. Proceedings of the 15th Biennial NSW weeds conference, Narrabri. (Industry and Investment New South Wales, Orange). pp. 19-28.

- Daly, T. (2013). Coastal saltmarsh. Primefact 1256. New South Wales Department of Primary Industries. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/459628/Coastal-Saltmarsh-Primefact.pdf (accessed 25 July 2017).
- Greater Sydney LLS, Local Land Services (2017). Sydney regional strategic weed management plan. 2017-2022. http://greatersydney.lls.nsw.gov.au/__data/assets/pdf_file/0010/722368/Greater-Sydney-Regional-Weed-Mgmt-Plan-29-June-2017_FINAL-web-res.pdf (accessed 4 August 2017).
- Hamilton, M. and Turner, P. (2013). Review of the NSW Threat Abatement Plan: Invasion of native plant communities by *Chrysanthemoides monilifera* (bitou bush and boneseed) 2006–2011. NSW Office of Environment and Heritage, Sydney). 77 pp.
- Heyligers, P.C. (2002). The spread of the introduced *Euphorbia paralias* (Euphorbiaceae) along the mainland coast of south-eastern Australia. *Cunninghamia* 7, 563-78.
- Hunter LLS, Local Land Services (2017). Hunter regional strategic weed management plan. 2017-2022. http://hunter.lls.nsw.gov.au/__data/assets/pdf_file/0004/722875/Hunter_Regional_Strategic_weed_management_plan_web-1.pdf (accessed 4 August 2017).
- Johnson, S.B. (2009a). New South Wales Weed Risk Management System. Background Information. Industry and Investment New South Wales, Orange. 54 pp.
- Johnson, S.B. (2009b). New South Wales Weed Risk Management System. Instruction Book. Industry and Investment New South Wales, Orange. 90 pp.
- Kelly, L.J.M. (2015). Patterns of sea spurge (*Euphorbia paralias*) invasion in New South Wales, Australia. Bachelor of Environmental Science Honours thesis, University of Wollongong. 66 pp.
- Keith, D.A. (2004). From ocean shores to desert dunes: the vegetation of New South Wales and the ACT. (Department of Environment and Conservation NSW, Hurstville).
- Mallick, S. and Askey-Doran, M. (2017). Sea spurge. Weed management guide. <http://dppwe.tas.gov.au/Documents/DPIPWE-Sea-Spurge-Guidelines.pdf> (accessed 28 July 2017).
- Panetta, F.D. (2015). Weed eradication feasibility: Lessons of the 21st century. *Weed Research* 55, 226-38.
- Parsons, R.F. (2013). *Limonium hyblaenum* (Plumbaginaceae), a cushion plant invading coastal southern Australia. *Cunninghamia* 13, 267-74.
- Rodrigo, T.M., Gibson, M., Versace, V.L. and Carr, G.W. (2012). Report on the biology and ecology of *Limonium hyblaenum* Brullo at Port Fairy, Victoria with respect to its invasive potential. Deakin University unpublished report.
https://www.researchgate.net/publication/236662021_Report_on_the_biology_and_ecology_of_Limonium_hyblaenum_Brullo_at_Port_Fairy_Victoria_with_respect_to_its_invasive_potential?ev=srch_pub (accessed 30 September 2013).
- RBG&DT, Royal Botanic Gardens and Domain Trust (2017). PlantNET - The Plant Information Network System of The Royal Botanic Gardens and Domain Trust, Sydney, Australia. <http://plantnet.rbg.nsw.gov.au/search/simple.htm> (accessed 28 July 2017).
- Scanlon, T. (2015). Effective weed management from theory to reality. *Plant Protection Quarterly* 30, 76-82.
- Walsh, N.G. (1996) Plumbaginaceae. In 'Flora of Victoria, volume 3', eds. N.G. Walsh and T.J. Entwisle, pp. 296-9. (Inkata Press, Melbourne).

A NEW PERMIT FOR AQUATIC WEED CONTROL: SHARK AQUATIC HERBICIDE – BROADENING CURRENT LABEL CLAIMS

Tony Cook, Technical Specialist Weeds, Tamworth, NSW DPI.

Email: Tony.cook@dpi.nsw.gov.au

INTRODUCTION Aquatic weed control is a sensitive, difficult and complicated topic. Much has to be considered; such as desirable aquatic organisms, whether the weed is submerged, partly submerged/floating or purely floating, volume and type of water body, method of control and the fate of the water being treated.

More often selection of chemical control is avoided due to various factors. Occasionally biological control is used, but often has limited opportunity as it requires large infestations, the environmental conditions must suit the vector and cannot control complex mixed infestations of weeds due to host specificity.

Mechanical removal is infrequently used but is best suited for floating aquatic weeds and against smaller infestations. The expense of this technique is very prohibitive.

Therefore, if chemical control is used it is often glyphosate based due to the relative benign effects on aquatic desirable organisms. The limitation of glyphosate is the inability to control submerged aquatic weeds.

LACK OF REGISTRATIONS

The choice of herbicides available for those wanting to control aquatic weeds is extremely limited. In contrast, every mode-of-action herbicide group has at least one product that is registered with a terrestrial use pattern. There are 19 modes-of-action (MOA) herbicide groups in Australia and only 6 cater for some form of aquatic weed control (Table 1).

Table 1. Label registered herbicides (MOA) that have some form of aquatic weed use pattern (does not include permitted uses via the minor use Permit system).

Active	Example product	MOA group	Weeds controlled	Situation – use pattern
amitrole	Amitrole T	Q	Cumbungi, phragmites, nutgrass, water couch and water hyacinth	Various aquatic situations
imazapyr	Arsenal	B	27 agricultural weeds	Irrigation channels
pendimethalin	Stomp	D	Barnyard grass and brown beetle grass	Irrigation channels
dichlobenil	Casoron G	O	Ribbon weed, pond weeds, milfoil and chara	Aquatic areas, but best used like a pre-emergent treatment

Active	Example product	MOA group	Weeds controlled	Situation – use pattern
diquat	Reglone	L	7 floating species – no submerged or partly emerged species	General aquatic areas
glyphosate	Roundup Biactive	M	10 emergent or floating species – no submerged species	General aquatic areas

Each herbicide listed in Table 1 has some reasonable limitations for its use. Both imazapyr and pendimethalin have limited uses; restricted to irrigation channels only. Only dichlobenil has some claim to control a limited number of fully submerged species and generally when the plants are dormant because it acts like a pre-emergence herbicide. The preferred choice, glyphosate, only has 10 species listed. However, there is likely to be more species on a range of minor use Permits to extend the use pattern of glyphosate. Diquat has excellent efficacy against a moderate range of floating aquatic species but its toxicological background may limit its use due to OHS concerns.

This list of registered aquatic herbicides has been static for many years and the introduction of aquatic friendly glyphosate was the last addition, approximately 20 years ago.

The incentives for companies to develop a label change for existing products or to develop a new product specifically for aquatic weed control is low. Risks that chemical companies have to consider when developing a new aquatic herbicide product or new use pattern for an existing are as follows:

- Need to produce toxicological data for non-target species (animals and plants).
- Fate of herbicide over time – potential for herbicide to move more freely compared to terrestrial situations. Hence, a need research to investigate this.
- Community perceptions of treating water bodies with chemical.
- Financial payback – large developmental investment for such a small potential market.

Consequently, there are many examples of aquatic weed species with very limited control options. This is best demonstrated Table 2 which used the Noxious and Environmental Weed Control Handbook as the source of information (Ensbej 2014).

Table 2. Range of chemical control options available for various aquatic weeds (other control options mentioned). Treatments include label and minor use Permit listed options.

Aquatic weed	Number of herbicide active ingredients available	MOA group herbicides represented	Non-chemical or alternative product options mentioned
Alligator weed	4	B, M & O	Bio-control
Azolla	1	L	Mechanical & orange oil
Cabomba	1	G	Physical removal & draining
Cumbungi	3	B, M & Q	Physical
Duckweed	1	L	Mechanical & orange oil
Elodea	1	L	Mechanical & copper
Horsetails	1	O	Physical
Hygrophila	2	B & M	Physical
Hymenachne	2	A & M	Physical
Mud Plantain	2	B & M	Physical
Leafy elodea	1	L	Mechanical
Long-leaf primrose	1	M	Manual
Ludwigia	2	I & M	Manual and burning
Sagittaria	1	M	Manual
Aquatic weed	Number of herbicide active ingredients available	MOA group herbicides represented	Non-chemical or alternative product options mentioned
Salvinia	3	B, L & M	Physical & orange oil
Water hyacinth	5	B, I, L, M & Q	Manual & bio-control
Water lettuce	4	B, I, L & M	Physical
Water lilies	2	L & M	Manual

Source: Noxious and Environmental Weed Control Handbook (Ensbey 2014).

The common feature from Table 2 is the dominance of weed species that only have one or two legal chemical options. Some of the more common, and hence more researched species, have four to five registered options, namely water hyacinth and alligator weed. It is worth noting that there are more aquatic weed species not mentioned in the Noxious and Environmental Weed Control Handbook. Weeds such as largarosiphon, water soldier, pennywort, water caltrop, yellow burrhead, parrot's feather, Egeria and hydrilla are not mentioned and are likely to have fewer registered chemical control options.

In situations where there are limited options and repeated chemical treatment, the chances of developing herbicide resistance increases. Fortunately there are no cases of herbicide resistant aquatic weeds in Australia at present, and thus complacency about aquatic weed management should not occur because such complacency has been a critical factor in the development of resistance in broad-acre farming.

A NEW PRODUCT

NSW DPI had investigated an existing active ingredient as a potential aquatic weed herbicide in the late 2000's. The active ingredient, carfentrazone, at the time was often used in broad-acre agriculture as a fast acting, non-residual, contact herbicide for early post-emergence broadleaf weed control. Carfentrazone is classified as a Group G mode-of-action herbicide, and other related active ingredients in this herbicide group include oxyflourfen (Goal[®] herbicide), aciflourfen (Blazer[®]), flumioxazin (Pledge[®]) and saflufenacil (Sharpen[®]). Various products are available for broad-acre that contain carfentrazone; Affinity[®] Force Herbicide and Hammer[®] were the first products on the market.

The research conducted by the Grafton Weeds Unit used the American product called Stingray[®], which contained 210 g L⁻¹ carfentrazone. All the products in Australia are slightly more concentrated at 240 g L⁻¹. The application for registration was lodged in 2009 and the Australian product, Shark[®] Aquatic Herbicide was approved in August 2011. It is the only herbicide registered for cabomba control (Table 2), and the only Group G herbicide noted in that list of registered products.

Shark[®] Aquatic Herbicide, although using an existing active ingredient, is a unique product due to its directions of use table and the critical comments required, ensuring excellent levels of control.

There are many features about this new use pattern/product that need to be highlighted. The dot points below cover some of these critical aspects of the Shark[®] label.

- It is only registered for Cabomba.
- Non-flowing water bodies – not flowing water.
- Must only treat 50% of water volume.
- If heavy rains are expected within 2 days, avoiding treating.

- Application rate – either 2 ppm or 830mL per 100,000L (hard to calculate 2 ppm, but an easy calculation formula helps derive the 830mL per 100,000L product required).
- Three types of application techniques, sub-surface injection, boom and high pressure hand-gun.
- Spring / Summer application preferred.

EXTENDING THE USES OF SHARK

One obvious constraint of this new product is the very limited weed spectrum on the directions of use table. Anecdotal evidence suggests that many weed species are controlled and that some method of obtaining a broader use pattern is essential. One such avenue is the minor use Permit system that the Australian Pesticide and Veterinary Medicine Authority (APVMA) regulate. A minor use Permit allows the use of a pesticide contrary to the label directions. They are specifically for smaller scale use (e.g. less than 10,000 treated hectares) and are granted if enough supporting data will allow enough confidence that the treatment is effective on the weed and non-harmful to the environment.

A proposal to obtain a minor use Permit was initiated by staff from Macspred[®] Australia and FMC Australasia Pty Ltd. A small committee with representatives from these two companies, regional weed officers and NSW DPI met in February 2016 to start the ball rolling with the minor use Permit application.

The rationale and benefits of obtaining a Permit were:

- A less expensive way to allow state-wide authorised use of a product.
- To allow weed managers greater option when controlling aquatic weeds.
- A way to gather data on its effects on other species.
- Greater volume of product is used and thus keeps the commercial success of the product going in such a niche market.
- Another mode-of-action herbicide that can be used to prevent development of resistance.

Initial discussions considered adding the proposed Shark[®] treatments to generic environmental Permit 9907. This Permit has broad categories of weed types, such as vine weeds, woody weeds and environmental weeds and as such it was hoped that another broad category, aquatic weeds, could be added and have Shark[®] as the treatment.

It was advised by the APVMA that if a minor use Permit be granted it should be a standalone Permit, particularly as this is a special case because of all the warnings and critical comments associated with the proper use of aquatic treatments. Furthermore, it was not possible to ask for a general aquatic weeds claim on the Permit, rather it had to be more weed specific using supporting evidence to back our claims. Fortunately, there were ample reports from overseas and Australia to generate a good range of aquatic weed species for the proposed Permit.

The evidence supported the highly effective control of floating weeds species such as duckweeds, water hyacinth, salvinia and azolla. Partly emergent / sub merged species were controlled to various degrees with some species showing more susceptibility than others.

After much delay, mainly due to data gathering, the APVMA granted a Permit on January 2017 for the jurisdiction of NSW. The Permit holder is NSW DPI and it expires on 31 March 2022.

THE PERMIT

Details of the permit can be easily obtained from the APVMA website. The Permit number is 83083, so by typing in the keyword search bar this number should find the Permit.

The current web address as of 29th July 2017 was: <https://portal.apvma.gov.au/permits>

A much lower rate of product is required to control the floating species, as seen below in the Directions for use Table. An application of 933 mL product over a hectare is considerably lower than the 830 mL of product per 100,000 L treated water volume. This lower rate for floating species is common sense as higher rates are required for submerged plant due to dilution effects as the product has to pass down through the water body to reach the submerged foliage.

Table 3. Directions for use Table within Permit number 83083.

Directions for Use:

Situation	Target Water Plant	Rate
NON FLOWING WATER BODIES	Floating Water Plants Azolla (<i>Azolla</i> spp.) Duckweed (<i>Lemna</i> spp., <i>Wolffia</i> spp., <i>Spirodela</i> spp.) Salvinia (<i>Salvinia molesta</i>) Water hyacinth (<i>Eichhornia crassipes</i>) Water lettuce (<i>Pistia stratiotes</i>)	933 mL product / ha (224 g carfentrazone ethyl/ha)
	Emergent and Submerged Water Plants <u>Suppression only</u> Alligator weed (<i>Alternanthera philoxeroides</i>) Water primrose (<i>Ludwigia peploides</i> ssp. <i>montevidensis</i>)	830 mL product / 100,000 L water (2 mg/L carfentrazone ethyl)
	CABOMBA (<i>Cabomba caroliniana</i>)	

A critical aspect of this Permit is the record keeping requirement, as described below (Table 4). The purpose of this is to gather data to build a case for expanding the weed species that can be controlled and those sensitive species tolerant of the treatment. The data

collected should assist the registrant of Shark[®] improve the current label and thus not just rely upon continual renewal of the minor use Permit.

Table 4. Record keeping requirement within Permit number 83083.

Record Keeping

1. The permit holder must maintain a record of the use performed under this permit. Specifically the records must include;
 - i) The date and location where the use occurred,
 - ii) Persons conducting the use,
 - iii) Area treated,
 - iv) Total amount of product used
 - v) Water quality parameters before and after treatment, and
 - vi) Surveys of biodiversity and other data to quantify system impact and recovery.
2. The records must be progressively maintained whilst the permit is in force and for a minimum period of two years from the date of expiry of this permit.
3. Upon a request being made, the records are to be provided:
 - a. Immediately if the request is verbally from an APVMA Inspector who has attended the premises
 - b. In the time specified in the written correspondence containing the request.

DISCUSSION

The granting of Permit 83083 is a significant boost for managers of aquatic weeds in New South Wales. It is a rare opportunity to experience the benefits of a new herbicide that has excellent activity against floating and submerged aquatic weeds. Other chemical options do not have this capability.

Weed officers are strongly encouraged to record their treatments as described in the Permit instructions and pay particular attention to other weed species that may be controlled, as well as recovery and survival of desirable species. There is likely to be more species controlled compared to what is stated on the permit as many species in Australia have not been thoroughly investigated. This data is crucial for obtaining a potential extended label claim for Shark[®] Aquatic Herbicide, as the present label is only limited to one species (Cabomba).

The inclusion of a different mode-of-action herbicide will greatly reduce the resistance selection pressure on commonly use herbicides such as glyphosate.

ACKNOWLEDGEMENTS

The successful granting of the Permit would not have been possible without the input from the following people; Terry Inkson, David Officer, Paul Wilcox, Ray Gurney, Chris McGill, Patrick Madden, Terry Schmitzer, Wendy Bushell, Elissa van Oosterhout, Suzanne Hayward and Grant Taylor.

REFERENCES

Ensby, R. (2014). Noxious and Environmental Weed Control Handbook – A guide to weed control in non-crop, aquatic and bushland situations, 6th Edition, NSW DPI, ISSN 1443-0622.

HIGH RISK WEEDS STUDY TOUR

Roger Smith

Natural Resources Coordinator
Orange City Council, PO Box 35, Orange, NSW, 2800
rsmith@orange.nsw.gov.au

SUMMARY Invasive weed species pose one of the greatest threats to biodiversity and primary production in NSW. It is the role of local government weeds staff, under current legislation, to prevent new high risk weeds from entering their region. As part of this role, weed officers undertake inspections of private and public land for high risk species, yet few in Central and Western NSW have had the opportunity to experience these weeds first hand. Weed officers in this region are also disadvantaged in their professional development as most work alone, have limited contact with neighbouring officers - especially in remote shires, and must travel vast geographic distances to obtain training. Agencies in the region have limited capacity to undertake training themselves, and in particular, they do not have the required experience, contacts or funds to organise a study tour for only one or two staff members.

The experience gained by weeds officers involved in the high risk weeds study tour will benefit all in Central and Western NSW through improved biosecurity and in their ability to provide better informed conservation and agricultural extension services. The latter is vital in preparing landholders - both private and public - for the new General Biosecurity Duty requirements under the *Biosecurity Act 2015*.

THE TOUR

Local Control Authorities and other government agencies are at the front line of weed control, working to minimise this significant threat. Weed officers are efficient and dedicated in their role, but in Central and Western NSW they have limited opportunities to undertake further professional development in new weed identification. A high risk weeds study tour was organised to visit sites where invasive weed species were present providing opportunities for weeds staff to see firsthand, weed species not yet present in their region, be exposed to new, innovative control techniques, opening up opportunities to collaborate with neighbouring regions and improve community extension services leading to a generational change in weed management and protection of biodiversity across the region.

Highly invasive or high risk weeds are of particular concern as they have the ability to establish rapidly in new areas, compete with native species for limited resources, can be toxic to animals & humans, destroy native habitats, choke waterways & inhibit passage through land, and negatively affect aesthetics of natural areas and agricultural productivity. The most effective way to manage invasive species is to prevent their initial incursion. The study tour has allowed weed officers to improve surveillance and management techniques, and boost cross-regional partnerships to ensure early detection of, and rapid response to, high risk weed incursions in Central and Western NSW.

The study tour set out from Dubbo and visited sites at Tamworth, Armidale, Coffs Harbour, Grafton and Moree over 5 days. The tour was heavily subsidised by funding provided by the Macquarie Valley Weeds Advisory Committee and the NSW Environmental Trust. Weed Officers from Local Control Authorities in central, western and southern NSW attended the tour which provided an ideal forum for networking and exchanging of ideas and experiences.

Targeted weed species included:

- Mexican water lily;
- alligator weed;
- water hyacinth;
- salvinia;
- tropical soda apple;
- Maderia vine;
- cats claw creeper;
- giant Parramatta grass;
- parthenium weed; and
- tiger pear.

The study tour was designed to facilitate a change in behaviour of local and state government weed officers, and through them the whole community, by enhancing identification skills, knowledge and understanding of integrated weed management.

Each of the sites allowed participants to observe the high risk weeds growing in their natural environments. Weed Officers from each of the focus areas gave the tour group an account of the weeds in their area whilst discussing management techniques and practices. Their experience in dealing with the high risk weeds was invaluable to tour participants.

Tour participants were given a questionnaire pre- and post-tour to gauge their knowledge of the focus weeds. Generally all participants had limited knowledge of each weed prior to the tour, but, upon the conclusion of the tour all participants had 100% knowledge of 9 out of the 10 weeds observed. The only weed which did not have 100% knowledge post tour was Cats Claw Creeper which had 96%. Flooding in the area at the time prevented tour participants from observing some weeds in their natural environment.

CONCLUSION

Whilst allowing Weed Officers to see the weeds in natural environments, the tour also funded the production of a Weeds DVD to be shown at field days and workshops across western NSW empowering land owners with the knowledge to prevent and/or deal with new weed incursions on their own land.

The number of new incursions prevented from establishing and infestations effectively destroyed and/or controlled will be reported back; as well as agencies, landholders, and community groups engaged in on-ground action for these and other weeds across 45

million hectares or 56% of NSW. This will help minimise the costs of weed control and impact on the environment; a monetary figure estimated to be greater than \$1.8 billion per year state wide. Our approach is proactive.

The high risk weeds study tour provided an opportunity for local weed officers to observe weeds which have the potential to invade their local government areas. Seeing is believing and tour participants certainly did see the potential impacts these focus weeds could have “on their patch”. The tour also provided an opportunity for weed officers to network with like-minded weed professionals.

ACKNOWLEDGEMENTS

I would like to thank the following study tour committee members: Melissa Gunn, Melissa Brennan, Lis Arundell, Rachel Bailey, Mick Ryan, Craig Bennett, Andrew Cosier, Andrew Gosper and David Wurst.

Thanks also to the Weeds Officers from the various areas we visited. Without their help the tour would not have been such a success.

Finally I would like to acknowledge The Environmental Trust for their financial contribution via a grant and also the Macquarie Valley Weeds Advisory Committee for its cash contribution.

EXTINGUISHING THE FLAME – FIREWEED CONTAINMENT IN THE ACT

By Jenny Conolly¹, Steve Taylor² and Chris Condon³

¹Invasive Species Officer, City Services, 500 Cotter Rd Weston 2611 ACT,
Email: Jenny.Conolly@act.gov.au

²Senior Weeds Officer, ACT Parks & Conservation Service, 500 Cotter Rd Weston 2611
ACT, Email: Steve.Taylor@act.gov.au

³Rural Services Officer, ACT Parks & Conservation Service, 500 Cotter Rd Weston 2611
ACT, Email: Chris.Condon@act.gov.au

SUMMARY

Fireweed (*Senecio madagascariensis*) is a Weed of National Significance (WONS) and a prohibited and notifiable pest plant in the ACT. Prior to 2014, isolated fireweed plants were occasionally detected on arterial roads leading into the ACT. These plants were quickly removed, with little follow-up control required. In 2014, the nature strips of several new suburbs (Crace, Forde, Franklin) were landscaped with couch turf from Sydney. This turf was contaminated with fireweed seed. Mass germination resulted and fireweed began to spread to surrounding reserves and open space. In 2015, infestations of fireweed were found at two urban pond shrub beds, in the suburb of Coombs. These infestations consisted of many advanced plants in flower and seed, producing a very large seed bank. The source was contaminated tube stock brought into the ACT. A major Biosecurity-type response, combined with ongoing and frequent follow up control, has contained and substantially reduced the size of all these infestations.

INTRODUCTION

Fireweed is a pest plant under the Pest Plants and Animals Act 2005. It is notifiable, prohibited and must be suppressed. There are localised infestations in the ACT. Adjacent NSW shires have isolated infestations, eg. Googong suburb. But nearby coastal shires have widespread infestations, eg. Shoalhaven and Eurobodalla.

When fireweed first appeared in the ACT, in 1990, it was thought that the ACT climate (hot dry summers, cold winters) would limit its spread. The mass germination of fireweed in contaminated couch turf in 2014, and contaminated planted tube stock in 2015, showed that this was wrong. Plants germinated on mass in autumn and plants grew and flowered through winter frosts. Germination continued into summer when there were cool changes combined with rainfall. Plants were detected spreading to neighbouring land.

Advice from NSW weeds officers was that a “zero tolerance of flowering fireweed” would be required to contain the spread because it is a very adaptable plant and prolific seeder. The NSW advice is consistent with fireweed literature: fireweed is an “opportunistic weed of degraded pasture, open bushland, grassland, suburban bushland, roadsides, disturbed sites, wasteland, parks and coastal districts” (Richardson *eta l* 2016); and fireweed “spread is principally by wind...and a large single plant produces from 25,000 to 30,000 seeds in a season” (Parsons and Cuthbertson 1992). This has guided the ACT Government’s resourcing and response to the infestations.

MATERIALS AND METHOD

In autumn and winter 2014, the Invasive Species Officer for City Services noticed numerous, suspicious looking, yellow flowered daisies, germinating in cured couch turf laid in the suburbs of Crace, Forde and Franklin (figures 1 & 2).

Plants were collected and identification confirmed by the herbarium as fireweed. Advice on risk and management was obtained from NSW DPI and NSW weeds officers. Using the NSW Weed Risk Management System, the risk for ACT lowland grasslands and grazing areas was determined as 'high', with a 'very high' feasibility of coordinated control (sites were all known, readily accessible, and source was known. This gave a management action of 'destroy infestations'.

Figure 1: Fireweed in turf at Crace Suburb



Figure 2: Fireweed seedlings in frosted off couch turf



An incident management team (IMT) was formed to mobilise resources and ensure thorough primary control, and tracing the source of the contaminated couch turf. Actions that were taken included:

- Checking all new developments for use of contaminated couch turf
- Determined source of couch turf (one grower in the Richmond area of Sydney)
- Line searches of nature strips in the suburbs of Crace, Forde and Franklin
- Engagement of an experienced contractor to assist experienced staff with search and destroy work
- Publicity, media and liaison with the Turf Industry Association (Turf Australia)

The IMT phase lasted 3 weeks. This has since been followed by:

- Weekly follow up control with experienced staff during germination and growth periods
- Liaison with developers and builders regarding sourcing clean couch turf and plant material
- Notifiable instrument (pest plant management plan) made for fireweed that allows the Pest Plants and Animals Act 2005 to be enforced (Australian Capital Territory 2014)

Most of the control work involved manual removal. There was some herbicide usage where there were dense seedlings. The Collector app that syncs with ArcGIS On-line was used to record infestations and control work. This has allowed analysis of the effectiveness of the containment efforts. In 2015, infestations of fireweed were discovered around two urban pond shrub beds in the suburb of Coombs. There were many mature and seeding plants. The source was contaminated plant tube stock from a fireweed region e.g. Sydney or the South Coast. A similar response to the nature strip infestations was successfully implemented.

RESULTS AND DISCUSSION

The results of control work at the Crace suburb and the neighbouring nature reserve, and Coombs Pond are presented below. These results mirror the outcomes at the other infestations areas. Collector app shows a large decline in the number of fireweed sites and plants. It also shows that no new infestations have been discovered in the neighbouring nature reserves.

Figure 3: Fireweed sites at Crace Suburb



Figure 4: Fireweed search and destroy at Crace suburb

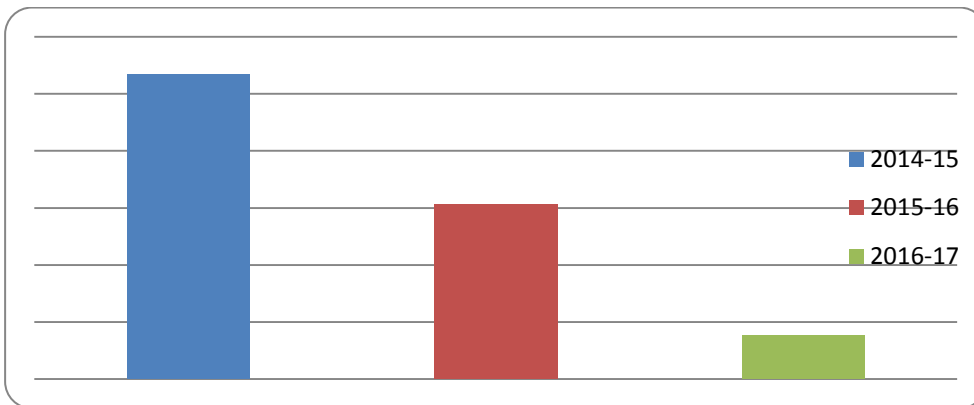
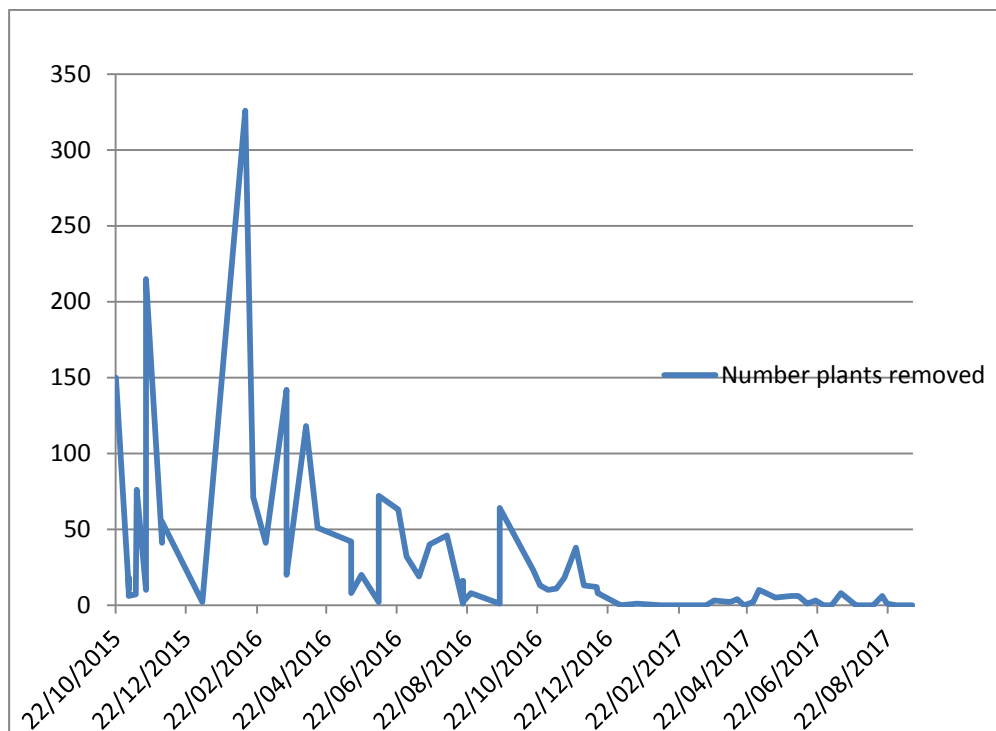


Figure 5: Fireweed plants removed from Coombs Pond East



Collector app mapping data shows containment has been achieved and the success with control can be attributed to four factors: use of experienced staff and contractors for search and destroy work, follow up control that targets seedlings, weekly follow-up control during germination and growth period, and cessation of further imports of contaminated couch turf and other plant material.

REFERENCES

Australian Capital Territory (2014) Pest Plants and Animals (Fireweed) Management Plan 2014 (No 1)

Notifiable Instrument NI2014—333 <http://www.legislation.act.gov.au/ni/2014-333/current/pdf/2014-333.pdf>

Parsons W.T., and Cuthbertson E.G. (1992) Noxious weeds of Australia, Inkata Press

Richardson F.J., Richardson R.G., and Shepherd R.C.H. (2016) Weeds of the South-East: an identification guide for Australia, 3rd Edition, R.G. and F.J. Richardson