2013 NSW WEEDS CONFERENCE

17th NSW Weeds Conference

"Weeds have no boundaries"

RSL Club, Corowa, New South Wales

9 - 12 September 2013

Conference Proceedings

Corowa Shire
MULWALA COROWA HOWLONG
...the choice

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NSW GOVERNMENT Department of Primary Industries

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Contents

CONFERENCE PROGRAM

Monday 9th September 2013

2-6pm	Registration @ Corowa RSL Club
2-5pm	Project Officers Meeting – Lone Pine Room
3-4pm	Weedmap Pro User group meeting – all welcome – Federation Room
4-6pm	County Council Managers Forum – Federation Room
6-7.30pm	Welcome Function: Corowa RSL Club – finger food provided. Reg Kidd 15mins & Mayor MC: Neil Hibberson. Note: bistro closes at 8:30pm

Tuesday 10th September 2013

	Opening session – Federation Room	
8am	Registration Corowa RSL Club in Foyer	
8.30	MC: Neil Hibberson	
8.35	Welcome to Country – Indigenous Elder	
8.45	Open by Corowa Shire Council Mayor, Councilor Fred Longmire	
8.50	Official Opening	
9.05	Keynote speaker - *Containment as a strategic option for managing plant invasions* – Dr Tony Grice, CSIRO Townsville	
9.35	Keynote speaker - *Weed management in NSW - exploring opportunities to improve weed management in NSW* – Dr John Keniry AM, NSW Natural Resources Commissioner	
10.05	MC: Neil Hibberson	
10.10	Morning tea and trade display in Auditorium (ground floor)	
	Morning concurrent sessions	
	Alternate control – Federation Room	**Raising the profile** – Lone Pine Room
Chair	Sarah Keir	Daryll Morris
10.30	*Alternative land management styles* – Mich Michelmore	*Making the move from traditional to contemporary weed management* – Jim Willmott
10.50	*The use of biological control agents to manage Salvinia molesta within the Hawkesbury/Nepean River* – Chris Stanfield	*Towamba Landcare – community leaders* – Ann Herbert
	Mid morning session – carrots and sticks - Federation Room	
Chair	Rod Ensbey	
11.15	*Don't let the truth get in the way of a good story* – Dr Stephen Johnson	
11.35	*APVMA Permits* – Karl Adamson	
11.55	*Biosecurity Legislation* – Philip Blackmore	
12.15	*Herbicide resistance in non-agricultural areas* – Tony Cook	
12.35	Questions for all speakers	
12.45	Lunch and trade display in Auditorium	
	Afternoon concurrent sessions	
	Jumping the fence – Federation Room	**The dirty dozen (WoNS)** – Lone Pine Room
Chair	Rex Stanton	Stephen Battenally
1.45	*Understanding the ecology of invasive unpalatable perennial grasses* – Roberto Distel	*The benefits of national weed initiatives for NSW: Past successes and future opportunities* - Hillary Cherry

2.05	*Species that are getting ready to jump the fence* – Dr Stephen Johnson	*Genetic analysis of native and introduced populations of the aquatic weed delta arrowhead: implications for biological control in Australia* – Raelene Kwong
2.25	*No boundaries for NRM on the far south coast* – Ann Herbert	*A success Story, the Cape Broom Psyllid; Potential of the Scotch broom gall mite* – Paul Sullivan
2.45	*Control of Cabomba in Lake Benalla and surrounding environs* – Tony Dugdale	*Bulgandramine mission restoration & rehabilitation* – Matthew Bailey
3.00	Afternoon tea and trade display in Auditorium	
	Afternoon session – Mapping remote sensing – Federation Room	
Chair	Mel Wilkerson	
3.20	*Robotic Aircraft and Intelligent Surveillance Systems for Weed Detection* – Salah Sukkarieh	
3.50	*Disaster mapping, data management & coordination post black Saturday fires: case study* – Lyn Terrett	
4.10	*Spatial invasion patterns in NZ Hawkweed* – Dr Peter Espie	
4.20	*Hawkweed surveillance in the alps* – Peter Terrett	
4.30	End of Session – housekeeping, social event info, Trade display – committee to chair	
4.45 – 6.00	NSW Weed Officers Association AGM - Lone Pine Room	
5.30 – 7.30	Social Networking Event @ D'Amico's Restaurant, Sanger Street, Corowa. Finger food provided	

Wednesday 11th September 2013

	Early morning session – Boys and their toys
7-8.30	Breakfast (BBQ) adjacent to Auditorium, sponsored by Weed Officers Association David Pomery to welcome / introduce Yamaha and other presenters
7am – 9.45	Trade display adjacent to Auditorium. *Yamaha RMAX Unmanned Helicopter* – Mike Johnson
8am	Day Registration in foyer
9.45	Morning tea and trade display in Auditorium
10.00	Paula Bosse, housekeeping, field trip info, dinner info
	Morning session – Passports for weeds – Federation Room
Chair	Paula Bosse
10:05	*NZ Hawkweed overview & current research results* – Dr Peter Espie
10.35	*Border Security – Spotlight on weeds* – Katrina Cuthbert
11.05	*The Detector Dog Contribution to Invasive Weed Location Management & Eradication - Bitou bush* – Peter & Charmaine Crumblin
12.05	Committee member point out (4 tour leaders). Leaders wait at bus and tick off delegate names. Lunch collection in Auditorium
12.30	Field Trips: Option 1 - Murray Meander; Option 2 - Bardi-grub Crawl; Option 3 - Fields of Gold; Option 4 - Glass and a half
5pm	Return to RSL Club from Field trips
6.30 for 7.00	Formal Dinner Corowa RSL Club - Federation Room sponsored by Local Government NSW, MC/Rob Ferguson, semi formal dress, bus transport Guest Speaker Don McLardy former Melbourne Football Club, Reach Foundation. Geoff Hudson, Local Government NSW. Auction of signed memorabilia will occur – all funds donated to the Reach Foundation. Announce next conference destination, Birgitte Verbeek, Conference Future Fund Committee. Awards – Weed Society

Thursday 12th September 2013

8am	Day Registration Corowa RSL Club foyer	
9.00	MC Rodney Anderson + Patrick Minogue, housekeeping, reflect on formal dinner, field trips	
	Morning session – Change is upon us – Federation Room	
Chair	Birgitte Verbeek	
9.10	*Weeds Training Comes of Age* – Harry Rose	
9.30	*NSW WAP – where it came from; where it is now; what is in the future?* – Syd Lisle	
9.50	*Future of weed management in NSW* - Geoff Hudson	
10.10	Questions for all speakers	
10.25	Morning tea and trade display in Auditorium	
	Mid morning concurrent sessions	
	Exploring the unknown – Federation Room	**Strategic approaches** – Lone Pine Room
Chair	Phil Blackmore	Mich Michelmore
10.45	*Early detection and management of water star grass under the NSW WAP* – Ben White	*Strategic weed management in protected areas of NSW* – Pete Turner
11.05	*Carrion flower, a novel invasive species in NSW* – Mark Hamilton	*Local weed control prioritisation mapping* – Neville Plumb
11.15	*All eyes focused on hawkweed eradication in Victoria – a partnerships approach* – Dr Karen Herbert	*Eastern Australian Boneseed Eradication Program* – Paul Martin
11.35	*Weeds in the sub-Antarctic wilderness of Macquarie Island* – Laura Williams	*Dee Why Creek Wildlife Corridor Project* – Jillian Macintyre
	Chemical control – Federation Room	**How to tame your gator** – Lone Pine Room
11:45	*Determining the efficacy of the herbicides endothal and diquat on the aquatic weed Sagittaria (arrowhead) in irrigation channels* – Tony Dugdale	*How to Tame Your Alligator* – Ian Borrowdale & Jason Carson
12.00	*Recent advances in Galenia control* – Tony Cook	*Snapping good time with the Alligator weed* – Jan Mitchell
12.15	*Comparison of use rates & treatment timing with Glyphosate to control Mexican Water Lily* – Mark Finlay	*Alligator weed in the Namoi river – a threatened species.* Charlie Mifsud
Chair	Adam Craig – Federation Room (allowed 5mins for delegates to move back)	
12.35	*Community involvement in the Atlas of living Australia: as it relates to biocontrol* – Paul Sullivan	
12:55	Lunch and trade display in Auditorium	
	Afternoon session – What are we protecting – Federation Room	
Chair	Steve Onley	
1.50	*Interconnections and Invasion: What it means for local biodiversity* - Dr Rachel Clancy	
2.05	*Why are we trying to stop weeds* – Andrew Cox	
2.20	Future generation – TBA	
Chair	Neil Hibberson & Robert Ferguson	
2.35	Conference wrap – Syd Lisle	
2.50	FINISH: Evaluation & Feedback complete – thank you. 3pm.	

Program subject to change without notice

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CONTAINMENT AS A STRATEGIC OPTION FOR MANAGING PLANT INVASIONS[A]

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SUMMARY Containment is a strategic option that is frequently advocated for dealing with invasive plants. It is often presented as the fall-back option when eradication is deemed unfeasible, notably when eradication attempts are abandoned. However, containment confronts the same needs for detection, delimitation and destruction of plants as eradication. Its main advantage is that the area to be managed is smaller. Its main disadvantage is that the time over which management is required is infinitely longer, assuming that eradication is successful and the containment effort is not abandoned. We argue that a containment program should be built around clearly defined containment units, consisting of an occupied zone and a surrounding buffer zone, at a scale that aligns with the plant's dispersal capacity. There will always be a probability >0 that some propagules will be dispersed beyond any practical buffer zone designed to cover the seed shadow of plants occupying the containment unit. This requires that, under a containment strategy, some resources should be invested in both the occupied zone, to reduce propagule pressure, and the area beyond the buffer zone to deal with the consequences of long-distance dispersal events. Containment is not always easier than eradication or the most cost effective alternative to it.

Keywords: Eradication, impact reduction, prevention.

INTRODUCTION

Various strategic options for countering plant invasions have been identified. The terms “prevention”, “eradication”, “containment” and “asset protection” (Grice 2009) are commonly applied to describe strategic options and, further, they have often been aligned with the phases of the invasion process (VDPI 2010). Prevention is logically prescribed for the pre-introduction phase when a species is absent from a targeted region. Eradication is usually deemed a prospect in the immediate post-introduction phase, when there are only a small number of localised populations. Once a species has become more abundant and has spread beyond a limited number of sites, the hope of eradication is usually abandoned and the strategist instinctively resorts to containment as the most logical option. Finally, once the species is abundant and widespread, ‘asset protection’ is generally advocated, focusing efforts on specific locations where particular assets are under threat from the invader.

Not all links between generic phases of an invasion process and strategic options have been systematically explored. There is an intuitively obvious relevance of prevention, at the continental or large regional scale, to the pre-introduction phases of a

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would-be invasion. There has also been considerable research on the feasibility of eradication and the factors that affect it with the general conclusion that eradication is likely to be feasible only when the total population is small, there are few infestations and the total area occupied by the invader is limited (Panetta 2007). High reproductive output, high dispersal ability and persistent soil seed-banks are demographic traits that are likely to make eradication less feasible. There is a considerable literature on the eradication of invaders, plants and animals, with more than 1500 papers published since 1919, the vast majority in the last 25 years (Grice *et al.* in prep.).

By contrast, there is a more limited research literature, only about 200 papers, on the containment of invasive plants, the earliest of these having been published in 1974 (Grice *et al.* in prep.). Many simply refer to containment as a strategic option, some provide some conceptual context for containment, some examine specific practical issues and deal with particular spatial scales and locations while others examine aspects of the effectiveness or feasibility of containment. The Australian weed management literature (strategy documents; management guides etc.) is replete with references to containment but these vary in how comprehensively it is addressed (Grice *et al.* in prep.).

In a series of papers since 2006 we have explored the idea of containment, how it might best be defined, factors that might influence its feasibility, its conceptual context, how it relates to other strategic options, in particular eradication, and the challenges it is likely to present in practice. This paper presents a synopsis of these ideas.

DEVELOPMENTS IN THE SCIENCE OF CONTAINMENT

When is containment an option?

There are two general contexts in which containment might be considered a strategic option: (i) as a strategy for exploiting plant species that are, could be, or are perceived to be commercially valuable and yet which also present or could present problems as weeds; and

(ii) in situations in which an invasive species that is not of commercial value has not filled its potential distribution in an area to which it has been introduced.

Containment of commercially exploited invasive species

Grice (2006) examined the first of these two options and, in particular, the prospect for containing what were labelled "commercial weeds", species that have, or could have commercial value and yet which are, or could be, invasive. Containment was described as "actively prevent[ing] a species from spreading beyond defined limits". Specifically in relation to commercially exploited species, containment was defined as "preventing a species from spreading away from sites where it has been planted".

Three sets of factors determine both invasion potential and the feasibility of containment of a commercially exploited species:

(i) the characteristics of the plant species to be contained;
(ii) the circumstances under which that species is cultivated; and
(iii) the characteristics of the broad landscape within which cultivation takes place (Grice 2006).

With these factors in mind, containment of a commercial species can be attempted by: (i) altering the form of the plant that is cultivated (e.g. using sterile forms of species whose commercial exploitation does not require reproduction in the field); (ii) altering the management regime under which it is cultivated (e.g. by grazing forage species so that their seed output is reduced); and

(iii) changing the management of the landscape within which the species is cultivated (e.g. site selection, controlling dispersal agents or burning outside cultivated areas to control fire-sensitive species (Grice 2006).

Few, if any, of the techniques can, on their own, guarantee that commercially cultivated but invasive species will not spread beyond locations in which they have been planted. They can at best reduce the probability of spread and/or the rate at which spread occurs. This analysis of commercially exploited invasive species raised the question of who might take responsibility for containment (Grice 2006).

A more detailed analysis of the socio-economic and legislative mechanisms that might be used for containing commercially useful but invasive species explored the "polluter pays" principle as an alternative to an approach in which the negative impacts are borne by those directly affected while others are free to benefit from cultivation (Grice *et al.* 2008, Clarkson *et al*. 2010). A list of species whose containment could be attempted using these approaches was provided and included pasture grasses (e.g. *Andropogon gayanus* Kunth, gamba grass), forage shrubs (e.g. *Leucaena leucocephala* (Lam.) de Wit, leucaena) and horticultural crops (e.g. *Olea europaea* L., olive) (Grice *et al.* 2008). Broad strategic options for dealing with commercially useful invasive species are to:

(i) prohibit cultivation (whether or not the species is already present in the country);

(ii) permit cultivation but have those negatively affected compensated by a third party;

(iii) encourage cultivators to take voluntary steps to prevent spread or reduce impacts; and

(iv) impose legislative measures on cultivators, for example, by allowing cultivation only under permit or restricting where, how and how much may be cultivated.

Options (iii) and (iv) could incorporate containment measures. Possible measures include voluntary or compulsory codes of practice, legislation that dictates specific containment measures, payment of bonds or levies, compulsory insurance against "escape" from cultivation and enterprise certification (Grice *et al.* 2008, Clarkson *et al.* 2010).

Grice *et al.* (2010) provided a breakdown of the species, landscape, management and social factors that influence the feasibility of containment of "contentious" plants. Species with an annual life cycle, frequent and/or high reproductive output, intractable dispersal mechanisms and high dispersal capacity, large reserves of long-lived seeds, frequent recruitment, short generation time and/or broad habitat preferences are likely to be more difficult to contain than species that do not have these traits. Containment is likely to be difficult in landscapes with a lot of highly suitable habitat, a high degree of connectivity between habitat patches and landscapes where access is difficult. Commercially exploited species that are cultivated in extensive production systems that require reproduction of the target plant, that are difficult or expensive to kill and yet are widely cultivated with little regulation, will also present major challenges to containment. Finally, species that are highly valued and for which there is a perception that they have little negative impact will also not be amenable to containment (Grice *et al.* 2010). This paper also stressed the fact that containment must target individual species at specific sites and introduced the idea of a "containment unit" and discussed it in relation to spatial scale. In the case of commercially exploited invasive species, it was proposed that individual plantings should be the targeted containment units whilst acknowledging that containment could be attempted at any scale.

Hypothetical containment unit

The hypothetical containment unit described by Grice *et al.* (2010) was conceived to consist of an occupied zone supporting established plants of the target species and a "buffer zone" that is deemed to not support established plants but which potentially receives propagules from the occupied zone. The buffer zone covers the species' seed shadow and its outer limit aligns with a hypothetical limit to the plant's dispersal capacity. Beyond the buffer zone is an "unoccupied" zone that is deemed to "neither (currently) support established plants nor receive viable propagules". Under this model, containment could be achieved provided plants emerging from seeds dispersed to the buffer zone are prevented from reproducing and containment measures could be entirely focused on the buffer zone.

Modes of failure of the hypothetical containment unit

Three types of breaches were conceived to threaten failure of the containment unit (Grice *et al.* 2010). These were Type I: plants reproducing within the buffer zone; Type II: propagules dispersing beyond the buffer zone; and Type III: plants reproducing in the "unoccupied" zone. These breaches might occur if plants establishing in the buffer zone are not detected; if plants in the buffer zone are allowed to reproduce; or if the hypothetical maximum dispersal distance is underestimated and consequent plants are not detected and are allowed to reproduce. In the event of breaches of one of these types, the strategic goal of containing the target species to the containment unit could only be maintained if a 'local' eradication program is instituted and successful (though it would not be essential to eliminate the seed-bank of the buffer zone). Alternatively, the boundaries of the containment unit could be modified to incorporate plants established and/or reproducing outside the original boundaries. A succession of breaches of a progressively expanded containment unit would constitute an accelerating collapse of the containment strategy (Grice *et al.* 2010).

Containment defined

Often, the term containment has been used without reference to a particular definition. The implication seems to be that an intuitive definition is adequate. Sometimes containment is defined simply as prevention of spread. We proposed a somewhat more rigid and perhaps less intuitive definition: **containment is deliberate action taken to prevent establishment and reproduction of a species beyond a predefined area** (Grice *et al.* 2012). This emphasises that containment as a strategic option will involve deliberate action, though this does not preclude the possibility, indeed the likelihood, that there will be many instances where a species' distribution is constrained by environmental factors such as climate and soil type. Our definition also focuses on establishment and reproduction rather than the perhaps more intuitive dispersal as the demographic process that is most critical for a species to expand its distribution. There are two reasons for this. One is that it is very difficult to directly manage many dispersal processes; measures can be put in place to interfere with some dispersal pathways, reducing the number of propagules they carry, but others are quite intractable. The other is that the focus on establishment and reproduction is consistent with our concept of a containment unit and how it can be applied – provided plants do not reproduce outside the defined occupied zone, the population can be considered contained. Finally, our definition stresses that containment must be applied to a predefined area in order to decide where containment effort is to be placed and it is important to assess the success or otherwise of those efforts.

Theory versus the practice

Containment is very commonly incorporated into the Australian weed management literature as exemplified by the strategy documents published for Australia's Weeds of National Significance (WoNS) (Grice *et al.* 2012). Of the 20 strategy documents published for WoNS in 2000, only two, those for *Tamarix aphylla* (L.) H.Karst. (athel pine) (ARMCANZ 2000a) and *Salvinia molesta* D.S.Mitch. (salvinia) (ARMCANZ 2000b) make no reference to containment. Several make reference to containment but only as a general objective (e.g. ARMCANZ 2000c), while others go further by providing or inferring some conceptual context, addressing the all important issue of scale and/or relating containment to its specific regional or national geography (Grice *et al.* 2012). Some of these strategy documents relate containment to dispersal processes and concepts such as "containment lines", "buffer zones", "core areas" and "non-core areas" (e.g. ARMCANZ 2000d), but these terms are not always used in the same way. For example, the concept of "core" and "non-core" areas seems to be variously related to more or less important infestations, higher and lower abundance, or to populations that are peripheral versus central to the overall. The term "buffer zone" is generally applied to an area surrounding a population of an invader.

In 2012/13 a new set of strategy documents was published for the WoNS, including those newly listed (AWC 2012a). The 31 available strategies all make reference to containment and take a more consistent approach than the year 2000 versions. Some provide a definition. For example, for *Rubus fruticosus* L. (blackberry), containment is defined as "control [of blackberry] on the outer edges of core infestations to prevent an increase in distribution" (AWC 2012b) and for *Jatropha gossypiifolia* L. (bellyache bush) it is "a weed management approach that aims to prevent an increase in the current distribution of a weed, by using weed control procedures to reduce the density of existing infestations and limit the dispersal of propagules" (AWC 2013a). Some of these documents relate containment to such concepts as "core infestation", "outliers" and "priority outliers". A core infestation is one that "is large and non eradicable at a defined scale" (AWC 2013b), or where plants are "widespread and have mostly reached their distribution limits but may expand in density within this limit" (AWC 2012b). The idea reflected in these terminological associations is that containment must involve dealing with individuals and infestations on the periphery of populations that are being targeted for containment, consistent with the "nascent foci" concept of Moody and Mack (1988). The common implication, though, is that containment is to be achieved by eliminating what at least some strategists label non-core infestations. That is, it requires a capacity for local eradication. Moreover, there is an implication in the combination of these definitions that makes containment the default objective for large infestations that cannot be eradicated when, in fact, containment is not necessarily the appropriate fall-back position.

Modelling containment

A simple geometric model was used to analyse the performance of eradication and containment strategies in the event of breaches to eradication or containment units (Fletcher *et al.* in prep.). This model considered six types of breaches of a hypothetical containment unit, refinements of the three types defined by Grice *et al.* (2010). A Type 0 breach was defined as a failure to remove an individual from the occupied zone before it dispersed propagules, a breach relevant only to eradication strategies. The analysis distinguished sub-types of both the Type II and Type III breaches defined by Grice *et al.*

(2010): Type IIa is where there is dispersal beyond the buffer zone from plants that reproduce in the buffer zone; Type IIb is where there is dispersal beyond the buffer zone because the dispersal capacity of the plant was underestimated; Type IIIa is where there is reproduction beyond but close to the buffer zone; Type IIIb is where propagules reach far beyond the buffer zone as a result of a long-distance dispersal event. The results suggest that containment is a valid fall-back position from eradication only in the event of Type I, Type IIa and Type IIIa breaches. The key conclusions from this work were that while containment can be a viable management option, it cannot always be justified and there is no guarantee that it will be cheaper than eradication. The main cost advantage of containment over eradication is that the area to be managed is smaller but this must be balanced against its main disadvantage which is that its timeframe is indefinite (Fletcher *et al.* in prep.).

CONTAINMENT PRINCIPLES

In order to expand its distribution in its introduced range individuals of a species must expend energy on structures to aid dispersal. Energy must also be expended to counter range expansion, that is, to contain the species. It is important that sensible decisions are made about whether a species can be contained with the resources available and how to achieve containment efficiently. On the basis of the work described above, we have distilled some tentative general principles to help make decisions about the containment of invasive plants (Grice *et al.* in prep.).

1. A “one size fits all” approach to containment is not appropriate. Containment strategies should be devised to suit the demographic traits of target species and the environments in which they are growing.
2. Containment presents the same challenges as eradication in terms of detection and delimitation. Whereas eradication requires that all individuals are found and destroyed, containment, at a minimum, requires only that all individuals outside the occupied zone are found and prevented from reproducing. However, containment should not be assumed to be an achievable fall-back position when eradication is abandoned as an option.
3. Containment requires a capacity for local eradication. This is to deal with populations that, in the long-term, will inevitably arise outside any practical buffer zone.
4. A realistic containment strategy should invest some resources in both the area beyond the buffer zone and within the occupied zone. Because there is never a fixed upper limit to a plant’s dispersal capacity, there will always be a probability >0 that some propagules will be dispersed beyond any practical buffer zone. The buffer zone can at best be expected to capture a large proportion of the propagules emanating from the occupied zone. Investment beyond the buffer zone should be aimed at detecting and eliminating populations arising from “long distance” dispersal. This is critical if the infestation is to be contained within the initial containment unit. Investment within the occupied zone may be less critical but should be aimed at reducing propagule pressure (Lockwood *et al.* 2006) on both the buffer zone and the area beyond it.
5. Containment units should be scaled to suit the dispersal capacity of the target species and address individual infestations or populations rather than operate at a whole-of-range scale.
6. A containment program should simultaneously cover all infestations or populations that are separated from one another by habitat suitable for the species.
7. One role of a containment strategy may be as a useful interim approach while other management measures are developed.

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WEED MANAGEMENT IN NSW
Exploring opportunities to improve weed management in NSW

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SUMMARY Despite all our efforts in research, biosecurity and on-ground control, weeds continue to establish, flourish and spread over our landscapes threatening the broader production and conservation outcomes community and governments seek. The NSW Government is currently undertaking a number of significant regulatory and institutional reforms across natural resource management, agricultural extension, biosecurity, native vegetation and local government. For example, the Government is establishing new regional Local Land Services to deliver production and conservation services and advice for NSW local communities. These reforms provide an opportunity to reflect on the outcomes we have achieved to date and how NSW could potentially improve the current arrangements for weed management in NSW. However, in the absence of a formal and comprehensive evaluation of weed management across the state it is difficult to clearly identify the problem we are trying to fix, and if there is a problem, how we can fix it at least cost and risk.

Despite this knowledge gap, it is clear that NSW needs to maintain a framework that delivers specific weed goals within the broader production and conservation outcomes community and governments seek. This framework would include clear directions on where we should head and how we should get there and tools to check and improve performance.

Keywords: Weeds, NSW, Local Land Services, biosecurity, reform.

ALTERNATIVE LAND MANAGEMENT STYLES
A test of reasonableness for invasive species enforcement

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SUMMARY Land managers choose conventional, organic, biodynamic, natural sequence, holistic, or other farming and land management styles to meet their own business or personal goals. There is considerable variation within these styles of farming, and it is sometimes difficult to precisely determine the style that a farmer is using. However, most alternative land or farming systems make equally valid contributions to sustainable land management, food production, and to community goodwill. When implementing any farming system, it is important to ensure that no regulations are broken. For weeds, the key legislation is the Noxious Weeds Act.

Councils have an obligation under the Noxious Weeds Act to enforce control and ensure noxious weeds do not spread to other properties. Councils have regulatory policy to meet this requirement. Whenever a single treatment does not immediately meet Noxious Weed control requirements of council, the farmer and the weeds officer will need to discuss tactics. Many councils also provide reasonable opportunity to allow alternate methods of control and the staged programs of integrated weed management through "approved Noxious Weed Control Property Plans." Control of some weed situations without the use of herbicides will be very difficult; however, the method of control is not the primary goal of the weeds officer. Focus on outcomes achieved, not on alternative land management styles.

Keywords: Conventional farming, organic farming, weed control outcomes

INTRODUCTION
Farmers and other land managers need to make the best effort to reduce weeds while maintaining long term economic or environmental productive capacity. The weeds officer needs to remember that the landholder will have these linked but different goals.

INTEGRATED WEED MANAGEMENT
Decisions on weed management should be integrated into district, property, paddock, and production plans (Box 1). Decisions should assess and consider likely outcomes of a treatment, and the range of subsequent decisions that will vary with circumstances. With any treatment (Table 1), the manager needs to know:

How it affects the weed
How it affects the desired species
How it builds on previous treatments
How it sets up for future treatments

Agronomy treatments are applied to directly affect production, but indirectly, may affect weeds. Weed treatments are applied to directly affect weeds, but indirectly, may affect production.

Box 1. Integrated weed management – patch and paddock control decisions within the property plan.

Integrated weed management uses a combination of different weed control techniques in combination with other land management techniques to maintain weed densities at manageable levels and to meet business goals. Integrated weed management is a systematic organisation of techniques to fit the weed situation. It considers the impacts of techniques on long term business goals, and the impacts of other business activities on weed outcomes. The system is interactive – an efficient and effective integrated weed management system is developed with comprehensive information about the property, land use, the weeds, and the control techniques available. Integrated weed management is a system of analysis and application – a way of thinking about weeds and their control at a particular time and place. Integrated weed management applies at the patch or paddock scale, but within the context of the property plan and the district situation.
An example of integrated weed management is where a landholder with a moderate infestation of serrated tussock in a general purpose pasture paddock chooses to spot treat the weed instead of broadacre treating it. While broadacre treatment may use a similar amount of chemical, and treats every plant in a very short time, the landholder is concerned about the off-target damage to the underlying grasses – this would have impact on production and leave the area open to further weed invasion. However, spot treatments would leave a considerable amount of grass for both production and to out-compete weeds, but some weed seedlings will be missed. In both cases, treated areas will need monitoring and there will be subsequent key decision points to meet both weed and business goals.

TREATMENT DAMAGE TO WEEDS AND VEGETATION

There are typically several desired outcomes from a treatment; such as reduce number of weeds, reduce competition with a crop, reduce contamination of crop product, deplete weed seed in the soil seedbank, reduce weed seed set, or reduce weed spread to other areas. With these outcomes there is a recurring trend – with increasing control of weeds there will be an increase in measures of the outcome being met. The meaning of 'control' is obscure as there is no single measure for control or for desired outcome.

When officers are familiar with treatments and how they affect weeds, they gain confidence to provide a recommendation. When officers are presented with any new treatment they may be required to use their knowledge of the type of noxious weed, its reproductive cycle and environmental factors and how these are being affected by the treatment. For class 4 Locally Controlled Weeds, the ultimate test is the question of fact of the ability of the plant to spread or to reproduce. The obligation to "continuously inhibit its reproduction" may require officers to undertake inspections more frequently to gather information regarding the activities of the landowner.

There is no general prescription to record the impact of herbicide or other treatment on weeds, crop or pasture. In treatment trials a comparison is made with an untreated reference plot. This may be impossible when monitoring general weed infestations. Damage is an overall assessment of the number of dead plants, dying plants, plants which will not reach maturity before the growing season ends, plants which may reach maturity, plants accidentally missed, and plants unaffected. Use Table 2 as a guide for general weed control and to record off-target damage to plants and patches.

Table 1. Agronomic and weed management tactics for best practice weed management in agricultural land uses (adapted from McGillion, T. and Storrie, A. 2006).

AGRONOMY TACTICS	**WEED TACTICS**
Agronomy tactics are applied to directly affect production, but indirectly, may affect weeds.	Weed tactics are applied to directly affect weeds, but indirectly, may affect production.
Product / crop choice and sequence	**Deplete weed seed in the target area soil seedbank**
Crop sequencing to minimise weed burden, disease, insects, soil erosion	Burning residues, hot water, steam
Cropping/cultivation	Encouraging insect predation of seed
Pasture establishment	Inversion ploughing or deep burial
Forestry	Autumn tickle
Allow natural regeneration of native scrub	Delayed sowing
Manage weeds in non-crop areas	Mulching
Improving vegetation competition	**Kill weed(s) (seedlings) in the target area**
Strategic grazing and rests	HERBICIDES*
Fertiliser use and placement*	Broadacre non-selective application to fallow and pre-sowing control
Disease and insect pest management	Broadacre selective post-emergent application in crop
Crop type	Broadacre selective pre-emergent application in crop
Sowing rate	Spot application
Row spacing	NON-CHEMICAL
Sowing depth	Paddock fallow and pre-sowing cultivation
Sowing time	Weed control in wide-row cropping with inter-row cultivation, shielded spraying or crop-row band spraying
Soil properties	Fire
Herbicide tolerant crops	Biological control
Fallow phase	Spot treatments by hand pulling, cultivation by hoe
Controlling traffic or tramlining	**Stop weed seed-set**
	In-crop weed management for seed-set control
	Spray-topping crop or pasture with selective herbicides
	Crop-topping with non-selective herbicides
	Wiper technology
	Crop desiccation and windrowing
	Slashing, silage and hay – crops and pastures
	Grazing – actively managing weeds in pastures
	Renovation crops and pastures – green manuring, brown manuring, mulching and hay freezing
	Change from sheep to cattle

Table 1. Continued.

	Prevent viable weed seeds within the target area being added to the soil seedbank Grazing crop residues Weed seed collection at harvest Narrow header trail Chaff cart Other options for weed seed collection at harvest Remove weed and destroy by burial, compost, fire **Prevent introduction of viable weed seed from external sources** **Prevent removal of viable weed seed from infested areas** Feed out weed free fodder; sow weed-free seed Vehicle / machinery hygiene Stock movement Fencing Shelter belts / windbreaks
* Fertiliser includes any product that will affect the availability of nutrients for the crop and weeds	* Herbicides includes application of registered products, and substances that directly affect plant growth, such as kerosene, diesel, pine oil, vinegar

Table 2. Rating of phytotoxic effects.

None evident	The plant is healthy
Negligible	Discolouration, distortion and/or stunting barely seen.
Slight	Discolouration, distortions and/or stunting clearly seen.
Moderate damage	Moderate discolouration, marked distortions and/or stunting. Recovery expected.
Substantial damage	Much discolouration, distortions and/or stunting; some damage probably irreversible.
Majority	Majority of plants damaged, many irreversibly; some necrosis; discolouration and distortions severe.
Most	Nearly all plants damaged, most irreversibly; some plants killed (< 40%); substantial necrosis and distortion.
Severe	Substantial number of plants killed (40-60%); much necrosis and distortion.
Very severe	Majority plants killed (60-80%); remainder show much necrosis and wilting.
Devastating	Remaining live plants (<20%) mostly discoloured and distorted permanently or desiccated.
Complete	Complete loss of plant and (or) crop yield.

TREATMENTS AND LAND MANAGEMENT SYSTEMS

Most farmers apply concepts of integrated weed management and may follow aspects of conventional, organic, biodynamic, natural sequence, holistic, or other farming and land management styles. As there is no single measure for weed control, and no single meaning for ‘control’, it is difficult for an observer to describe how one treatment or land

management system is better than another. For a weeds officer wishing to stop further spread of a weed, the single desired outcome is to prevent reproduction.
There are many treatments that fit into several land management styles. When a treatment is promoted that does not immediately meet requirements of the Noxious Weeds Act, the weeds officer may consider integrated weed management, alternate methods of control, and the staged programs through "approved Noxious Weed Control Property Plans." Control of some weed situations without the use of herbicides will be very difficult; however, the method of control is not the primary goal of the weeds officer. Weeds officers need to focus on outcomes achieved, not on the alternative land management style.

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MAKING THE MOVE FROM TRADITIONAL TO CONTEMPORARY WEED MANAGEMENT[A]

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SUMMARY This paper is an account of how Far North Coast Weeds, a Weeds County Council in the Far North Coast Region of New South Wales, transitioned from a traditional weed management model to a contemporary weed management approach. This area of New South Wales has the highest biodiversity values in the State and includes all the right climatic and geographic ingredients that allow it be a true garden of Eden for weed domination. Operating in one of the most complex and challenging weed management environments in Australia this County has actively adopted and espoused the goals of the NSW Invasive Species Plan in all facets of its business planning and service delivery. Through sheer determination, innovation and belief this approach has inspired stakeholders who were once negative and disengaged to embrace and unite to tackle weeds strategically to return the highest return on investment and the greatest public benefit.

Keywords: Management model, management approach, return on investment, public benefit.

INTRODUCTION

The Far North Coast County Council, trading as Far North Coast Weeds, is constituted under the New South Wales *Local Government Act 1993* and is also a Local Control Authority under the New South Wales *Noxious Weeds Act 1993*. It is responsible for administering the *Noxious Weeds Act 1993* across the Tweed, Byron, Ballina, Lismore City, Richmond Valley and Kyogle Local Government Areas; an area adjoining the Queensland border to the north, Tenterfield Shire to the west and Clarence Valley Council to the south. The operational footprint encompasses an area of approximately 10 290 km^2.

The population of the County is over 250 000 people and the greater North Coast Weed region contains over 400 000 people. The County also borders with the south-east corner of Queensland, which has a population of over four million people. The area is blessed with a sub-tropical environment delivering high rainfall and temperature onto fertile soils, creating the highest level of biodiversity in NSW and many beautiful and iconic natural assets from world heritage rainforests to some of the best beaches in the world. These natural assets support a large tourism industry with millions of interstate and international tourists visiting the region each year. The region supports a broad range of primary industries including beef production, soybeans, sugar cane and a variety of high value horticultural groups.

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Challenges

Having a great climate and geography, combined with a highly disturbed landscape, increasing development, tourism and population growth produce all the necessary ingredients for a weed heaven. Council's operational footprint and the greater North Coast region are located within a complex environment for invasive weed management. The region contains a large number of widely established weeds overlaid with the continual introduction of new incursions, occurring at an increasing rate. The Council has the dubious honour of being home to the highest diversity and abundance of noxious weeds in New South Wales. This scale ranges from endemic weeds such as *Cinnamomum camphora* (L.) T.Nees & C.H.Eberm. (camphor laurel) and *Ligustrum lucidum* Aiton (broad-leaf privet) through to Class 1 weeds such as *Miconia calvescens* DC. (miconia) and *Hymenachne amplexicaulis* (Rudge) Nees (hymenachne).

Traditional weed management

Historically, the Council's approach, through all best intentions, has been based on a traditional style of weed management. Traditional weed management can be defined as a reactive style that invests effort into managing weed species after they have already become widely established and are highly resilient to interference. Negative impacts on environmental, economic, social and cultural values and assets are felt and we respond, or are forced to respond, to these impacts. This approach is visually appealing both politically and publicly. Under a traditional weed management style stakeholders can see a response to weeds that they themselves were feeling, seeing and sensing. Under this management style stakeholders measure the effectiveness and performance of a Local Control Authority on its response to decreasing the negative impacts of widely established weed species. This results in short-term gains and inefficient utilisation of precious resources. It does however appease many stakeholders and thus politically this approach has, and continues to be, supported in many areas.

Transitioning to a contemporary management style

The late 1980s and through the 1990s saw the introduction of a more strategic weed management approach with higher order national and state strategies directing a strategic approach to invasive species management, not just of weeds. The introduction of the NSW Invasive Species Plan and NSW Weed Action Program has provided the momentum for a fundamental shift in weed management from a reactive traditional approach to a more strategic contemporary approach.

Contemporary weed management can be defined as a proactive style that relies on successfully targeting investment to where it will return the greatest benefit or the highest cost:benefit ratio. While this sounds like common sense, it takes real commitment and ongoing effort to ensure this approach is adopted in all planning and operational activities , at an all of Council level. Even in the absence of such direction from higher order strategies, plans and funding programs, a contemporary weed management program would still be the most common sense way of spending limited resources to produce the most successful weed management outcomes.

Moving from traditional to contemporary management styles

The following is a brief account, with examples, of how Council moved from traditional to contemporary management styles, grouped into management, community and governance categories.

Preventing new weed incursions

- This focused on the high risk weed species that were likely to come over the border from Queensland and identified possible pathways and vectors of introduction.
- Targeted extension material for these weeds was created and disseminated to key stakeholders.
- Deliberate targeted surveillance of high risk entry pathways and recognised high risk sites occurred.
- There has been increased cross-border collaboration and intelligence sharing with biosecurity stakeholders.
- The website was upgraded to promote new high risk weed species and a ‘report a weed’ function was added.
- Targeted extension platforms were designed and implemented using separate but integrated mediums promoting the ‘why’, ‘how’, ‘who’ and ‘what happens after’ questions.

Rapid response to eradication and containment

- Development of high priority weed management plans occurred with a view to implementing a rapid response to detect and control such weeds, and build the capacity of the general public to identify and report new weed incursions.
- There was high risk pathway and site surveillance, and control, where necessary.
- The purchase of specialised plant increased strategic abilities to detect and control new incursions rapidly.
- There was incorporation of information on high priority weeds into targeted extension initiatives, including the training of key weed management stakeholders external to Council.

Targeted management of established weed species

- The use of resources was promoted to where they would provide the greatest strategic and public benefit on widespread weeds management.
- There was increased collaboration and engagement with stakeholders involved in coordinating and/or implementing the control of established weeds.
- There was focused resourcing of the operational, extension and control activities towards the promotion, use and recording of biological control agents.
- There was increased partnering tofocus on building improved connectivity between researchers, Council staff, and industry and community stakeholders.

Building community ownership and commitment

- The development and implementation of multiple extension platforms across our diverse stakeholder base occurred. Although these platforms utilised different mediums, they were all interlinked to espousing the four key goals of the New South Wales Invasive Species Plan (NSW DPI 2008).
- Involvement and participation by all stakeholders through both physical and electronic mediums was encouraged.
- Creating and maintaining a database of stakeholders and actively engage and interact within this network helped. This interaction and engagement was carefully measured to cultivate participation, commitment and ownership, producing a momentum that transitioned stakeholders to a contemporary weed management style.

- Improved information systems created increased quality, quantity and availability of information to support strategic decision making, benchmarking and resource allocation processes.

Governance

- Cyclic education of councillors and key decision makers to the benefits of a contemporary style was needed.
- The targeting of key staff in multiple government and community organisations to become champions of change and harnessing their influence to bring about changes in both planning, implementation and review processes was undertaken.
- There was incorporation of the Invasive Species Plan goals and objectives into the business plans within our own organisation and throughout as many other stakeholder organisations as possible.

RESULTS AND DISCUSSION

The transition to a contemporary weed management approach has provided directional clarity to both County staff and councillors, however it has not been a simple shift from one style to the other. It has taken considerable effort and time to bring all facets of Council's business planning and corporate direction towards this contemporary style. Building momentum to change organisational culture and beliefs requires the ability to take staff with you through "walking the talk". For most noxious weed professionals, changing to a contemporary approach is just plain common sense. Noxious weed officers were practicing contemporary weed management long before the introduction of the Invasive Species Plan and New South Wales Weed Action Program.

Occasionally weed management professionals will unfortunately continue to be pressured to return to the traditional style. This pressure eventuates from the external influence of certain stakeholders on Local and State politicians, often forcing backward steps and a waste of precious resources to 'window dress' an issue. When this occur it is frustrating, time consuming and sends the wrong message to the public.

Adopting and continuing to practice a contemporary style of weed management takes courage and discipline from all councillors and employees. The incorporation of the Invasive Species Plan goals in all facets of Council's business planning, and then having the commitment to follow this through to service delivery, will assist in countering pressures external to the organisation. To positively support the transition, this County was very active in communicating the new style to the community. This communication was targeted, and utilised a number of different mediums and electronic platforms overlaid with avenues for increased stakeholder participation and continued engagement.

Communicating contemporary weed management needs to be cyclical, both internally and externally. An example of this would be the need to provide an overview of the County's weed management approach after each local government election or providing annual high priority weed species training for employees from different government, industry and community groups.

CONCLUSIONS

Moving from traditional to a contemporary weed management regime has provided this Council and its employees with directional clarity and confidence in meeting future challenges. There have been pitfalls and setbacks along the way, however there is now more resilience to change and a better community engagement. The transition is producing greater stakeholder connectivity and interaction with an expanded acceptance of the need to constantly review and evaluate weed management approaches to ensure limited resources are targeted to where return on investment is highest and public benefit is greatest.

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THE USE OF BIOLOGICAL CONTROL AGENTS TO MANAGE SALVINIA MOLESTA WITHIN THE HAWKESBURY/NEPEAN RIVER

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SUMMARY Biological control agents are seen by many as the silver bullet for outright weed control. In reality, comprehensive weed control by a single control agent or mechanism is rare. This presentation is an operationally based overview implementing the *Cyrtobagus* weevil to manage *Salvinia molesta* populations. It will also address the challenges faced in a highly used recreational resource, the successes, the failures and the knowledge gained from working with this biological control agent for the past seven years.

INTRODUCTION

The Hawkesbury/Nepean river system encircles Sydney, Australia's largest capital city. This waterway has a history of human impact for nearly as long as Sydney itself, the river is many things to many people, from a source of seafood, to irrigation nourishing local agricultural products; fruit, vegetables, beef and turf through to recreational activities such as boating, fishing, water skiing and paddling. However, this much loved river suffers under man's impact and its wounds are visible for all to see: erosion, sedimentation, human development, land clearing and urban runoff.

High nutrient loads entering the river act as a catalyst, triggering explosions in exotic and native aquatic plant growth. The river contains numerous aquatic weed species from nuisance species to serious, noxious weed species such as *Salvinia molesta* D.S.Mitch (salvinia), *Eichhornia crassipes* (Mart.) Solms (water hyacinth) and *Egeria densa* Planch (leafy elodea). When the ideal balance of high available nutrients, low flow rates and increased water temperatures occur, problematic weed populations begin to rapidly build, often in rarely accessed stretches of river.

Salvinia is one such weed species, an aquatic fern that reproduces asexually through plant division. Salvinia has the ability to double its size within 72 hours. If left undetected, massive infestations can build within a relatively short time.

The rapid, choking growth of this weed literally shuts down the river, blocking sunlight from penetrating the water column, destroying agricultural pumping infrastructure and creating an impenetrable barrier that poses a threat to all living things associated with the waterbody.

Treatment of this menace requires an integrated approach, using herbicide, mechanical harvesting, containment booms, public awareness campaigns and the use of biological control agents. No single management technique had been proven successful in eradicating this species from the Hawkesbury/Nepean river. However the experiences Hawkesbury River County Council have had with the Cyrtobagus weevil hold promise that a cheap, reliable and sustainable agent of control – when correctly managed, will successfully control a high proportion of Salvinia infestations within aquatic environments.

RELEASE OF CYRTOBAGUS SALVINAE

Summer/autumn 2005 saw over 40 kilometres of the Hawkesbury/Nepean river heavily affected by Salvinia molesta. Herbicide application had proved unsuccessful and socially unpopular, while mechanical harvesting, although effective, came with an unsustainable price tag. A biological control agent (*Cyrtobagus salvinae*) has been shown to potentially control large infestations of Salvinia with little in the way of culturing required to sustain populations. However, initial releases were met with skepticism and a general lack of understanding of weevil biology and its predation upon Salvinia.

Success was forthcoming in a number of stretches of the river however, no consistency could be found at that time to repeat and expand on the successes that had been achieved. Leaping forward to December 2011, a Salvinia infestation of over a hectare was being held behind a containment boom within the Nepean river at Castlereagh. Phone calls began flooding into the Hawkesbury River County council offices from members of the public, concerned that the weed was growing uncontrollably and could repeat the 2005 event that caused so much anger and frustration within the community. The action, however was underway. Three cubic metres of Salvinia, laced with Cyrtobagus weevil had been released into this infestation and monitoring had shown that insect numbers were building.

Continous monitoring has shown that that the weevils had been active. The rate at which the Salvinia was being affected was encouraging. In mid January 2012, 80% of the Salvinia was discoloured and sinking due to weevil activity. The Salvinia infestation had been reduced to 2% of its peak coverage and still falling when assessed in early February 2012. This is the procedure in which council manages Salvinia infestations and where this biological control agent has the best results.

It has been found that weevil populations will be effective in a broad range of aquatic situations. The best levels of control have been from the Hawkesbury/Nepean river system where a range of factors such as high dissolved oxygen levels, high light levels and assistance from river flows to bring Salvinia to collection points, creating a perfect environment for weevil establishment. Large, open farm dams with a minimum average depth of two metres provide a similar environment to the river. Smaller farm dams and waterways have also been successful although this success is dependant on a number of factors including dissolved oxygen levels, overhead canopy cover and exposure to wind.

Locations where weevil introduction has had little effect include: water bodies with an average depth of less than a metre, dense overhead tree canopy, extremes in pH readings, long established Salvinia infestations that do not provide the much needed secondary growth stage of the Salvinia plant or dams that have been unsuccessfully treated with herbicide.

STRATEGIC PLANNING FOR WEEVIL NURSERIES

Making the most of the Salvinia weevil does require some strategic planning, with the primary consideration being the availability of weevils to introduce into Salvinia infestations. After the success of the Salvinia control on the Hawkesbury/Nepean river the off river nursery site was lost through a flooding event, and other sites that had previously held weevils had also lost their colonies. It was at this point council had a stroke of luck. Whilst carrying out a private property inspection upon a farm dam the noxious weeds inspector noted that the Salvinia upon this dam had “that weevily look about it” and subsequent sink tests conducted on this infestation revealed dense populations of the Salvinia weevil. A number of landholders had previously contacted council regarding control methods for the Salvinia infestations on their water bodies. The decision was made to work with these landholders to introduce weevils into their dams and billabongs on the proviso that council could return and collect weevils for as long as they the colonies persisted.

Six active weevil nurseries have now been established at different locations across the county to ensure a ready supply to introduce into new infestations of Salvinia as they are detected.

KEYS TO SUCCESS

A number of practices could facilitate weevil success:

- Choose your battles. If you believe a particular infestation can be controlled with weevils and there is little risk of the Salvinia moving off site, the agent could be introduced, followed by constant monitoring of establishment and the associated Salvinia damage.
- Prepare a contingency plan: If the weevils are not effective or the Salvinia infestation needs to be controlled as an urgent priority, chemical or mechanical control may be required to treat the infestation.
- Allow weevils time to establish: Council has had rapid success from weevils in water bodies with optimum conditions, while other sites have taken 12 -18 months to see visible progress.
- Ensure translocated weevils and material is free of contaminant aquatic vegetation: This is especially true when moving material between different catchments or across LGA borders.
- Educate the community: An important role of any weed manager is to build capacity amongst the community. Biological control agents do work and it may be the preferred control method in certain sensitive aquatic sites. It is necessary to promote alternatives such as the weevil as an integrated approach across the landscape rather than relying on a single form of control.
- When tackling Salvinia in rivers and creeklines, it is important to manage weed movement through the use of weed containment booms for a number of reasons:
    1. Restrict the movement of Salvinia into downstream areas,
    2. Provide a nursery site for weevil populations to build and spread,
    3. Allows monitoring and collection of material from a single site,
    4. Water flows naturally bring upstream Salvinia plants to the weevil population.
- Engage landowners with off river infestations of Salvinia and propose a transparent, mutually beneficial agreement to create weevil nurseries: The goal is to create weevil supplies at a number of sites to ensure viable insect numbers are available when needed.

Salvinia is a weed that can occur in many waterways. A co-operative effort between government, non-government agencies and private landholders will ensure the best region wide control results. Sharing knowledge and control experiences, and providing mentorship to those with less experience are crucial pieces to the Salvinia puzzle.

Salvinia weevils are not the silver bullet for the total eradication of this insidious weed species, however they can be an asset to tackle large weed infestations that are difficult to treat, or in areas that are tidal influenced or are in sensitive in nature. As part of an integrated management program to control Salvinia infestations, weevils can be used as an additional labour force allowing other resources to be deployed into areas where traditional control techniques are more successful.

TOWAMBA LANDCARE – COMMUNITY LEADERS
A community driving land management at the catchment level

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SUMMARY The formation of Towamba Landcare was a result of conversations between a group of local landholders discussing weed management both on their own land and more broadly within the Towamba River catchment. Initially focusing on noxious weeds and their management, the group has seen the value of broader property management planning in the fight against weeds and has been involved in a number of projects, all with weed management as a key component. The group has successfully involved the Department of Primary Industries, Bega Valley Shire Council, National Parks and Wildlife Service, Forests NSW and private forestry companies in its weed management planning and programs, particularly serrated tussock management. The Towamba experience demonstrates the strength of a grass-roots approach to weed management and its evolution from a purely weeds focus to exploring much broader land management issues and integrating weed and pasture management into whole of farm planning as a recipe for success. It shows that a committed group can coordinate actions across all land tenures, involve all land managers, and hold them accountable. It demonstrates a capacity to identify specific issues that may require a more targeted approach through the formation of the Serrated Tussock Working Group. The groups continue to be community-driven and pride themselves on their inclusiveness, self-sufficiency, ability to adapt and their successes over the last twenty-one years.

Keywords: Catchment management, community drivers, weed management.

THE FIRST STEPS

Towamba Valley, situated in the south east corner of NSW in Bega Valley Shire, is bounded by the Great Dividing Range to the west, State Forests to the Victorian border twenty km south, and low timbered ranges to the east and north. Much of the catchment is forested and managed for conservation in National Parks or forestry activities undertaken by private forestry companies and Forestry Corporation of NSW.

Cattle grazing is the primary agricultural enterprise, with some sheep and mixed grazing and smaller enterprises such as orchards, vineyards and olive production. The key weeds threatening the catchment include serrated tussock, African lovegrass and St John's wort with blackberry and prickly pear also affecting some areas. Fireweed, too, is of increasing concern.

In 1992, a group of four landholders in the Towamba River valley were discussing the threat of African lovegrass invading from the Bega River valley and the more general risk noxious weeds posed to their enterprises and the local rural community more generally. Each member of this group was a relative newcomer to the valley, having purchased working grazing properties ranging from 270 to 450ha, and so came with a fresh and possibly different outlook on land management and how a catchment community could work together.

The early success of the Landcare group was due to the dedication of these four people, their determination to drive any actions from the farmer base, motivate their neighbours to take action as a community and to the individual farmers' concerns about loss of income due to pasture degradation caused by incursion of weeds.

Strong support from the then DPI agronomist, Harry Kemp, despite his initial scepticism as to the likelihood of such a group achieving positive outcomes, was a key to early successes. Harry had a history with the valley, connecting well with landholders, supporting, advising and assisting a number of them in getting loans in the early 1980s and providing information and advice over his years as DPI agronomist.

The Serrated Tussock Working Group, formed in 1994, comprises many of the same members as the Landcare group, but focuses more on the single issue of serrated tussock management in the valley. Again, it is driven by the community, with a strong push to have NSW Government agencies and Council part of the group and reporting to the group.

Both groups have continued to evolve and change as they continue to widen their land care interests and embrace a broader environmental perspective to include such issues as management of native pastures for production and pasture and grazing management to protect and enhance Endangered Ecological Communities (McPherson 2013; McPherson and Dorrough 2013).

THE STORY

The road travelled by any Landcare group is often difficult, with the weight of organisation, recruitment and day-to-day running often resting on the shoulders of one or two people; the result being that they burn out and there is no-one willing to take their places. Consequently, the initial energy and enthusiasm is lost and the group disintegrates.

The grass-roots nature of Towamba Landcare, backed by strong leadership and an early membership of 85, was important and contributed to its success but these factors alone do not guarantee longevity. Membership has waxed and waned, with the group sometimes almost ceasing to exist.

It hit a low spot six years ago with a membership of only four people. It was then that a Project Officer, a respected local farmer, was employed part-time, funded through Southern Rivers CMA and Council. His task included providing support to the Landcare group and overseeing a series of projects that would benefit individual landholders but also the wider community. These projects had a variety of environmental objectives but all had significant weed management components.

From this point and with the continuing support of the Project Officer the group has been re-built into an active group committed to better property management but with an increasing understanding of the value of a catchment-wide approach to broader natural resource management.

Part of both groups' success lies in making personal contact with landholders as the starting point. Active members make it a policy to door-knock new residents and have a chat to them about weed management, what Landcare is doing in the valley and what support could be offered on their newly acquired properties. In the past, a Weed Manual produced by the Landcare group early in its life provided local weed management information to new landholders.

Critical also to the success of any group are several factors

- Identifying what the majority wants
- Ensuring that others are comfortable with outcomes over the long term
- Flexibility in addressing issues
- Acknowledgment of individuals' work
- Choosing speakers to stimulate debate

Towamba Landcare focuses on intelligent pest management and is involved in many natural resource management activities in the valley including

- Management of a water-sharing plan for irrigators, landholders and Towamba valley townships
- Coordination of community programs such as Rabbit Calici Virus releases
- Group riparian weed control walks
- Employing Koori workers to undertake weed control, particularly along the Towamba River corridor
- Coordinating a NSW Environmental Trust- funded project to protect three Endangered Ecological Communities by native vegetation rehabilitation and effectively managing weeds
- Neighbour programs to support landholders having temporary difficulties managing weeds
- Weed control on Council roadsides – weed identification training

The social side of activities is important for both groups. Meetings centre round a barbeque or other social gathering and all become a good place for sharing of information in a relaxed and friendly environment. Individuals can freely discuss issues affecting them with Working Group meetings seeing each landholder give a report on their successes and failures to the group. These include reports from State land managers, privately held forests managers and Council. Any management issues are discussed with the aim of resolving them and commitments are sought, particularly from the agencies, for on-going work and dates of proposed actions.

CONCLUSION

While discussing the history of the groups with the four founding members, the issue of the geographic remoteness of the valley and its importance in the success of Towamba Landcare was raised. The valley is isolated, surrounded by timbered hills that are mostly either National Parks or managed for forestry, both by the State and private investors. Sense of community is very strong and, even with new landholders moving into the area, that community remains strong and self-sufficient.

The determinedly self-help and the bottom-up approaches, with the community owning the groups and deciding where and how they want to allocate their resources and what external support they want has seen management decision-making stay within the community. A vigorous and committed group led and supported by a funded and respected local with local knowledge and an effective local network has reinforced that sense of community.

Methods have been refined over the twenty one years of the life of the groups. A new community engagement model takes a systems approach at the locality level, identifying weaknesses in previous approaches and taking action to address them. There is an increasingly strong focus on three noxious weeds (serrated tussock, African lovegrass and St John's wort), with a rabbit management program linked closely to weed management and this direction is one the community has chosen.

The community has been instrumental in ensuring the local control authority better targets its weed management programs including roadsides and inspections through an effective consultation process. It has involved State Government land managers and held them to account. It has supported those in the area if they are having genuine difficulties but are seen to be trying and has asked that each of its members 'go the extra mile' in their weed control programs. It has listened to its community and provided the sort of field days and workshops they want, delivered with a local perspective.

Towamba Landcare currently has a membership of over eighty who manage about 70% of the cleared land in the valley with active Working Group members totaling about 30. The role of the Project Officer has been to support both Landcare and the Working Group, coordinate activities, listen to the community and through their concerns and advice, identify landholders who may need some support to become effective weed and pasture managers.

While it has remained independent of the requirements of funders by being largely self-supporting in the financial sense and wholly self-supporting as a community, it has identified funding opportunities to target specific issues, weeds and areas that affect the Towamba catchment – its catchment. It has stood on its own many feet and maintained its individuality.

ACKNOWLEDGMENTS

My thanks to William Wentworth, Derek Lewis, Michael Beatty and Terry Carson for an afternoon of conversation in March, their continued passion for effectively managing weeds through better property management and their dedication and hard work with Landcare and the Working Group. Thanks to Len Gazzard for his guidance and commitment to this model and to all the people involved with Towamba Landcare and the Serrated Tussock Working Group who have been, and continue to be, an inspiration to me and others.

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DON'T LET THE TRUTH GET IN THE WAY OF A GOOD STORY

The declaration of weeds that affect the environment started in 1907 in New South Wales[A]

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SUMMARY It is often claimed that the declaration and management of weeds that impact on the environment is a relatively recent occurrence. This story has shaped the development of legislation, policy and investment in New South Wales weed management programs. Unfortunately, like most good stories, it is not entirely accurate. To claim that the management of weeds that impact environment values in New South Wales is only a recent development is to ignore the historical record. In saying this, there is some evidence to suggest that weeds that impact on environmental values are now better managed in New SouthWales, particularly under the *Noxious Weeds Act 1993* and the *Threatened Species Conservation Act 1995*.

This paper examines the first 25 years of weed declarations in New South Wales comparing these to current declarations. The paper summarises in excess of 1300 and 2100 declarations under the *Local Government Act 1906* and the *Local Government Act 1919* respectively. Weeds declared in New South Wales during the period 1907-1931 affected both primary production and the environment. The importance of some weeds then managed has waned such that stinkwort (*Dittrichia graveolens* L. Greuter) and inkweed (*Phytolacca octandra* L.) are of little current concern, and are now not declared. In contrast, many weed declarations are similar to those today, for example Bathurst and Noogoora burr (*Xanthium spinosum* L. and *X. occidentale* Bertol., respectively). In such cases we need to ask whether the battle against these weeds over the last 105 years has been successful.

Keywords: Noxious, native, exotic, impacts.

INTRODUCTION

The New South Wales government has a long history of legislating to manage weeds that impact on primary production, the environment and the community, including on our cultural heritage. Although there was some parliamentary debate over possible legislative management of weeds well before the year 1900, it was not until the enactment of the New South Wales *Local Government Extension Act 1906*, and later the *Local Government Act 1906*, that Municipalities and Shires/Councils were able to apply to the State Governor to declare a plant (or animal) to be noxious within their area.

It was a requirement of the *Local Government Extension Act 1906* that occupiers or owners were "*to extirpate and destroy the plants or animals on the land*". Notice was to be served requiring such control within three months when any noxious plant or animal was found "*growing or living upon any land*" and that (if)

> "*at the expiration of such period, the plants or animals have not been so extirpated and destroyed or reasonable efforts have not been made to so extirpate and*

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> *destroy them, the council may forthwith extirpate and destroy them and any reasonable expense so incurred by a council may be recovered in any court of competent jurisdiction from the occupier, or if there is no occupier from the owner of the land"* [council also had powers of entry].

Councils were required to do the same on "*any land vested in or leased by it or upon any public place or reserve under its care or management*".

Similar requirements were to be enforced under the superseding New South Wales *Local Government Act 1919* in that all occupiers of land with noxious plants (and animals) were required to "*destroy such plants and animals and…thereafter keep the land free therefrom*". Notices for control were to be "*not less than two months*" and councils could enter to "*destroy noxious weeds and recover costs*". A £50 fine could be applied for failure to comply.

The *Local Government Act 1919* was the chief legislative instrument for the management of weeds until a revision of that Act in the early 1990's. At that time, the noxious weed requirements were removed from the 1919 Act and placed in the New South Wales *Noxious Weeds Act 1993*. Since then, local control authorities (generally local government areas) have been responsible for noxious weed control functions. [The revised New South Wales *Local Government Act 1993* was also tabled in parliament at the same time]. Weed management in New South Wales has been aided by subsequent legislation, for example the New South Wales *Threatened Species Conservation Act 1995* and legislative amendments to the *Noxious Weeds Act 1993*, for example Johnson *et al.* (2013).

This paper summarises the first 25 years of weed declarations in New South Wales (1907-1931). A comparison between these historic declarations and those of today is made. The most common weeds declared during the period 1907-1931 are listed and the possible reasons for declaring these weeds are examined. Whether or not the continued declaration of these species has been legislatively successful is discussed.

METHODS

Copies of the New South Wales Government Gazette were examined at the State (Mitchell) Library of New South Wales, in Sydney. Notices made by Local Governments, Municipalities and Shires were listed in the index of each quarterly volume: only those relating to noxious plants were recorded. The collated data were sorted to remove duplicate notices (the same species declared in the same local government areas two or more times) and to standardise common and scientific name spelling and terminology. Genera and species names were checked using RBG&DT (2009-2013) and updated as necessary.

For ease of comparison between the different Acts listed above, this paper separates the data into two sets; firstly for declarations from 1907-1918; and secondly for declarations from 1919-1931. This paper reports on the identity of the top ranked weeds declared (by number of areas declaring the weed), the total number of plants declared during each time period, the number of exotic and native species declared and, for a first at that time, which species were declared across the state. The probable reason why these species were declared is summarised and compared to current (2012) declarations contained in Weed Control Order 28 of the *Noxious Weeds Act 1993*.

RESULTS AND DISCUSSION

Weeds declared noxious 1907-1931

Seventy eight weed taxa were declared noxious during 1907-1918 and 119 taxa were declared during 1919-1931. Only three taxa declared noxious during the first period were not declared after 1919.

Increased problems posed by 'new and emerging' problem species may be one reason why many more exotic species like *Ailanthus altissima* (Mill.) Swingle, *Anredera cordifolia* (Ten.) Steenis and *Chondrilla juncea* L. and natives like *Cassinia arcuata* R.Br., *Kunzea ambigua* (Sm.) Druce and *Sclerolaena birchii* (F. Muell.) Domin were declared after 1918.

There is a high degree of similarity in the top 20 ranked species declared under the *Local Government Act 1906* (*Local Government Extension Act 1906*) and those declared under the *Local Government Act 1919* (Table 1). *Xanthium spinosum* L., *X. occidentale* Bertol., the species aggregate known as *Rubus fruticosus* L. and *Centaurea calcitrapa* L. were the most commonly declared species during both periods. The year 1920 also saw the introduction of "all of state" declarations for the two *Xanthium* species, *Hypericum perforatum* L. and *Moraea collina* Thunb. (probably *M flaccida* Sweet and *M. miniata* Andrews).

Comparison of weeds declared noxious 1907-1931 to 2012

Of the 26 top ranked weeds during 1907-1931, eight are no longer declared, that is *Cirsium vulgare* (Savi) Ten., *Dittrichia graveolens* L. Greuter, *Arctotheca calendula* (L.) Levyns, *Argemone ochroleuca* Sweet, *Datura stramonium* L., *Nicotiana glauca* Graham, *Phytolacca octandra* L. and *Solanum cinereum* R.Br. There are likely to be many reasons for these removals including better control measures, but also that some of these species are now present in their full geographic range and that enforced control is no longer warranted. By way of contrast, all *Opuntia*, *Rubus fruticosus* and *Lantana* species are still declared and this aids ongoing control and asset protection efforts, the latter two taxa being two of the original 20 Weeds of National Significance (WoNS). With only limited exceptions, nearly all top ranked species that were declared in 1907-1931 and that were declared in 2012 were Class 4 species in 2012 (Table 1): Class 4 noxious weeds are "Locally Controlled" and "*pose a threat to primary production, the environment or human health, are widely distributed to an area to which the order applies and are likely to spread in the area or another area*".

Probable reasons weeds were/are declared

With notable exceptions, most weeds were declared in 1907-1931 for the purposes of primary production. It is likely that only eight (12%) of weeds declared during 1907-1918, and 11 (9%) during 1919-1931, had primary production or partial environmental/primary production impacts.

Having said this, it is also important to note that a small but significant number of what are considered today to be environmental weeds were first declared during this period, particularly during 1907, that is *Chrysanthemoides monilifera* subsp. *rotundata* (DC.) Norl., *Ulex europaeus* L. and *Eichhornia crassipes* (Mart.) Solms, but also in 1911 with *Cytisus scoparius* subsp. *scoparius* (L.) Link, and *Anredera cordifolia* in 1920.

A case study involving the species aggregate that until recently was known as *Rubus fruticosus* best illustrates how legislation to enable the management of weeds impacting on environmental values is not a recent occurrence. While the passing of time clouds the reason why this species aggregate was first declared in New South Wales, in the Lismore Municipality in 1907, a statement accompanying the declaration for the same taxa in the Municipality of Kiama in 1921 indicates that it was "*becoming detrimental to farm and home* [native?] *lands*". While there is some evidence to suggest that weeds that impact on environmental values are now better managed in New South Wales, particularly under the *Noxious Weeds Act 1993* and the *Threatened Species Conservation Act 1995*, the historical record clearly suggests that legislation was used to manage weeds that impacted the environment from as early as 1907.

Table 1. Plant taxa declared noxious during the period 1907-1931, compared to current (2012) declarations. Scientific names are those currently used by RBG&DT (2013). Up to 3 common names that were used to identify the species in the New South Wales Government Gazette are listed in descending order of use.

Scientific name	**Common name/s**	**Number of areas declared in (and rank order)**		**Current (2012) declared areas and class** (total=123)
		1907-1918 (total=239)	1919-1931 (total=212)	
Xanthium spinosum	Bathurst burr	214 (1)	All (=1)	86 (Class 4)
Rubus fruticosus (species aggregate)	Blackberry, English blackberry, English bramble	107 (2)	98 (7)	All (Class 4)
Centaurea calcitrapa	Star thistle, True star thistle, Chinese burr	91 (3)	106 (5)	21 (Class 4)
Xanthium occidentale	Noogoora burr, Ditch burr	83 (4)	All (=1)	86 (Class 4)
Rosa rubiginosa	Sweet briar	82 (5)	63 (10)	41 (Class 4)
Echium plantagineum	Paterson's Curse, Blue weed, Purple bugloss	63 (6)	84 (9)	41 (Class 4)
Cirsium vulgare	Black thistle, Scotch thistle, Spear thistle	59 (7)	31 (16)	Not declared
Carthamus lanatus	Saffron thistle, False star thistle, Woolly thistle	49 (=8)	86 (8)	1 (Class 4)
Dittrichia graveolens	Stinkwort	49 (=8)	100 (6)	Not declared
Arctotheca calendula	Cape weed, Cape dandelion, Cape marigold	42 (10)	24 (=20)	Not declared
Lantana camara [now declared as *Lantana* spp.]	Lantana	41 (11)	52 (11)	All (3 Class 3 and 120 Class 4)
Argemone ochroleuca	Mexican poppy, Binneguy, Prickly poppy	30 (12)	51 (12)	Not declared
Datura stramonium	Thorn apple, False castor oil plant, Green stem thornapple	29 (=13)	46 (13)	Not declared
Hypericum perforatum	St. John's Wort	29 (=13)	All (=1)	35 (Class 3) and 78 (Class 4)
Eichhornia crassipes	Water hyacinth	27 (15)	15 (=26)	All (97 Class 2, 17 Class 3 and 9 Class 4)
Nicotiana glauca	Tobacco plant, Tree tobacco, Native tobacco bush	23 (16)	34 (15)	Not declared
Phytolacca octandra	Red ink plant, Inkweed, Dye berry	17 (17)	25 (19)	Not declared
Opuntia stricta	Prickly pear	15 (18)	10 (=39)	All (Class 4)
Lycium ferocissimum [and *L. barbarum* from 1920]	African boxthorn, Barbary box thorn, Chinese box thorn	14 (=19)	21 (=22)	84 (Class 4)
Marrubium vulgare	Horehound	14 (=19)	12 (=34)	27 (Class 4)
Ricinus communis	Castor oil plant	14 (=19)	21 (=22)	1 (Class 3) and 34 (Class 4)
Moraea collina [probably both *M. flaccida* and *M. miniata*]	Cape tulip, African weed, Jonquil	2 (=47)	All (=1)	14 (Class 4)
Alternanthera pungens	Khaki weed	8 (=27)	41 (14)	11 (Class 4)
Proboscidea louisianica	Devil's claw	1 (=56)	29 (17)	33 (Class 4)
Solanum cinereum	Narrawa Burr	13 (22)	27 (18)	Not declared
Onopordum acanthium subsp. *acanthium*	Scotch thistle, Heraldic thistle, Cotton thistle	12 (=23)	24 (=20)	34 (Class 4)

Exotic and native species declarations

Native plant species have both positive and negative impacts on primary production, the environment and the community. While the negative impacts of native plants probably most impacted on primary production in the past, over-abundance of these species (often the result of human activity) is also likely to have impacted environmental values in those times.

Eight native Australian weed taxa (10%) were declared noxious during 1907-1918, while these eight and an additional eight native weeds (a total of 13%) were declared during 1919-1931. The eight taxa common to both time periods were *Bursaria spinosa* Cav., a *Macrozamia* spp., *Olearia viscidula* (F.Muell.) Benth., *Persicaria hydropiper* (L.) Delarbre, *Salsola australis* R.Br., *Sclerolaena muricata* (Moq.) Domin, *Solanum cinereum* and *Swainsona galegifolia* (Andrews) R.Br. As stated earlier, it is not clear why many of these species were declared, excepting those which had explicit primary production impacts, e.g. *S. galegifolia* and the *Macrozamia* species which almost certainly caused animal poisoning.

Has the continued declaration of weeds been successful?

Around 40% of the weeds first declared during the period 1907-1931 are still declared over 105 years later. Additionally, over half the top ranked weeds from this period now exclusively have Class 4 (Locally Controlled) declarations. This clearly indicates that the original control measures that encouraged eradication, that is initially 'extirpation and destruction', and later 'destruction and keeping the land free of these weeds' have clearly not been successful.

The primary aim of legislation relating to noxious weeds is to remove weed externalities such that spread from infested areas to non-infested areas (covering the entire geographic range of spread) has not been achieved, as the relative large number of current declarations of these species illustrates. This generalisation appears to hold true for nearly all of the top ranked weeds. The most obvious exception to the above generalisation is that of *E. crassipes*, which is still largely restricted to eastern New South Wales, even though relatively small infestations are well known from several areas within the Murray Darling basin.

Of those species removed from declaration, it is likely that newer forms of control, including biological control, have reduced the threats posed by the species, as have newer technologies and practices.

In conclusion, while it is true that declaration may have helped slow weed spread since 1907, two inescapable conclusions remain:

1. that there is a need to continue to review noxious weed declarations in New South Wales, particularly those species that are currently Class 4 (Locally Controlled) weeds to ensure that legislative outcomes are continuing to be achieved; and
2. that, in a climatically diverse state such as New South Wales, some weeds obviously have no boundaries as to how far they can spread.

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APVMA PERMITS

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SUMMARY In 2009 the Federal Government began reforming the regulation of agvet chemicals in Australia. These reforms aim to reduce regulatory burden on business and support agriculture while maintaining the protection of people and the environment. These reforms have now become a legislated reality. Alongside these changes the Australian Pesticides and Veterinary Medicines Authority (APVMA) continues to offer an off-label and minor use permits system to facilitate safe chemical access and legalise chemical use for Agricultural sectors that are not well serviced by a Registrant based model of approved label uses. Environmental weed control is one section of Agriculture that is not well serviced by the current Registration system as most uses continue to be approved only under permit. So what are the issues involved in gaining approval for environmental weeds and how do Weeds Officers tackle a complex modern regulatory system to achieve good outcomes?

BIOSECURITY LEGISLATION, DISPERSAL OF LOCAL WEEDS AND THE TORT OF PRIVATE NUISANCE[A]

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SUMMARY Following the Australian Government, many Australian states are considering replacing a raft of biosecurity laws with a single biosecurity statute: for example Queensland is much more advanced in this process than New South Wales. Biosecurity law is generic by nature and relies on a number of all encompassing definitions. Biosecurity law can also apply to noxious weeds but would be limited to species that pose a significant threat to the economy, environment and/or community. This type of law aims to prevent or limit the impacts of external costs created by the spread of weeds (or other pests or disease) to new areas. It is inefficient when used to limit the dispersal of established local weeds. Civil tort law, however, may offer a remedy to landholders harmed by ongoing and uncontrolled dispersion of such local weeds.

Keywords: General biosecurity obligation, biosecurity matter, biosecurity event, external cost.

INTRODUCTION

The Beale Review on National Biosecurity Arrangements (2008) recommended the consolidation of biosecurity functions into a single organisation which would operate under a single statute. The Australian Government is leading the way with a bill to replace the *Quarantine Act 1908* currently before the Senate. Some of the states are also following this lead. The Queensland government has drafted the *Biosecurity Bill 2011* for the previous State parliament and the New South Wales (NSW) and Victorian governments are discussing proposals closely based on the Queensland bill at departmental levels.

BIOSECURITY DEFINITIONS

The Queensland *Biosecurity Bill 2011* attempts to create general statutory arrangements for the management of all biosecurity eventualities. To do this, it creates generic definitions applicable to biosecurity management, viz:

Biosecurity considerations

The triple bottom line, that is, the economy, environment and community with the

- economy including industry, production, market access, tourism, employment and transport;
- environment including natural ecosystems, native flora and fauna, and biodiversity; and
- community including lifestyle, community infrastructure, social cohesion, human health and well-being, and cultural values.

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Biosecurity entity
A person or business who keeps, or premises where a thing is kept, more than a threshold number of designated animals, plants or other biosecurity matter.

Biosecurity event
Something that has happened, may happen, or is happening, that was caused, or that may be or may have been caused, by biosecurity matter which has had, is having, or may have a significant adverse affect on a biosecurity consideration.

Biosecurity risk
The risk of an adverse effect on a biosecurity consideration caused by, or likely to be caused by, biosecurity matter, dealing with biosecurity matter or a carrier, or carrying out an activity relating to biosecurity matter or a carrier.

Biosecurity matter
- an animal, plant or living thing, other than a human, or part of a human;
- a disease, including a prion; and/or
- a contaminant.

General biosecurity obligation
The Queensland bill also creates a duty which applies to all persons dealing with, or carrying, or carrying out an activity with biosecurity matter.

A person has an obligation to:

- take all reasonable and practical measures to prevent or minimise the biosecurity risk;
- prevent or minimise adverse effects on a biosecurity consideration when dealing with the biosecurity matter, or carrier, or carrying out the activity;
- minimise the likelihood of causing a biosecurity event, and limit the consequences of a biosecurity event caused by dealing with the biosecurity matter, or carrier, or carrying out the activity; and/or
- not do, or omit to do, something if the person knows, or ought reasonably to know, that doing, or omitting to do, the thing may exacerbate adverse, or potentially adverse effects of the biosecurity matter, carrier or activity on a biosecurity consideration.

The provisions of the bill apply to declared biosecurity matter but many of the provisions, including the general biosecurity obligation, also apply to un-declared matter if this matter could create a biosecurity event. Several of the management tools proposed by the bill can be applied to both declared and undeclared biosecurity matter. Under the bill many existing noxious weeds could be declared as biosecurity matter but local noxious weeds (New South Wales Class 4 equivalent) are excluded by the requirement that declared biosecurity matter must have a significant impact on a biosecurity consideration. In Queensland, this exclusion has no consequence as local government in that state has the power to declare local weeds under the Queensland *Local Government Act 2009*. It is unlikely that local government in New South Wales would gain an equivalent power.

WHY ARE WEEDS DECLARED?

Weed spread and ongoing dispersal of established weeds create harm to the economy, environment and the community (Blackmore 2008). Various methods can be used to try to prevent this harm, or to provide a remedy to individuals who have suffered harm from this cause.

The problem of weed spread

Spread of a weed species is the occupation of new areas (Auld *et al.* 1978/9, Forcella, 1985). Weed spread creates external costs (Menz and Auld 1977, Pannell 1994, Jones 2000). External costs occur when the actions of individuals impose unintended impacts on others. Pannell (1994) describes several approaches to abating the impact of external costs, these being:

- the market;
- a Pigovian tax; and
- regulation;

The market

The use of the market as a method of managing external costs and its associated problems, is discussed in Blackmore (2005). The market is not an effective method as externalities are a form of market failure (Pannell 1994).

A Pigovian tax

This is a tax which aims to internalise external costs to the entities which create those costs (Pannell 1994). It is commonly referred to as the “polluter pays principle”. The Australian governments’ carbon tax is a Pigovian tax. This approach is most suitable where the external cost is constant such as pollution from factories (Baumol 1972).

Regulation

Regulation is the standard government approach to prevent or limit the creation of external costs caused by weed spread (Burns 1974, Menz and Auld 1977, Pannell 1994, Jones 2000). This has been the case in New South Wales for more than 100 years (currently the *Noxious Weeds Act 1993*) and more than 150 years in Victoria. Regulation is most effective when applied to weed incursions into new areas and to emerging weed populations (Hobbs and Humphries 1995). When used to limit the dispersal of widespread weeds, regulation can be anti-competitive and inefficient (Carter 2000), except where the majority of the community support compulsory control of a widespread local weed.

CIVIL TORT LAW – A POSSIBLE ALTERNATIVE TO REGULATION

In situations where landholders are being harmed by the ongoing dispersal of established weeds (local weeds) civil tort law might create an opportunity for the landholders themselves, rather than government, to take responsibility for regulating the impact of those weeds. This could be achieved by seeking to apply the law of private nuisance to landholders who cause harm to others by failing to limit the dispersal of local weeds. Preston CJ in *Robson v Leischke* at para 42 defined private nuisance as

> “an excessive act or omission which is an unreasonable interference with, disturbance of, or annoyance to a person in the exercise or enjoyment of his or her ownership or occupation of land or some profit or right used in connection of the land.”

The tort of private nuisance and its application to the spread of things naturally on the land is discussed in Blackmore (2011). *French v Auckland City Corporation* is the landmark private nuisance case in relation to weed spread (Burns 1974). This New Zealand case was about the dispersal of variegated thistle (*Silybum marianum*) seed and other weeds from land owned by the City to land occupied by the plaintiff. French had made considerable efforts to control weeds including variegated thistles on his land but the City's attempts at weed control were cursory. French was successful in his action, even though variegated thistle continued to be widespread on his land and was not a noxious weed in the district.

A nineteenth century British case, *Proprietors of Margate Pier and Harbour v Town Council of Margate*, a case involving the responsibility for removal of an accumulation of rotting seaweed in Margate harbour, subject to the *Nuisances Removal Act for England 1855*, may also have relevance to weed spread. It could be argued that unrestrained weed spread would be in breach of the general biosecurity obligation. A landholder could be liable in nuisance where the landholder failed to prevent ongoing dispersal of a locally widespread weed. The dispersal would need to be by natural means, that is wind, water or wild or feral animals, rather than by some negligent act, c.f. *French v Auckland City Corporation*. However the degree of harm must be significant. Harrison J in *Hill v Higgins* at para 49 stated that

> "to be liable in nuisance, the annoyance or discomfort must be substantial and unreasonable".

Burns (1974) reported that the test for nuisance caused by nature was established in *Goldman v Hargrave*, an action brought both in nuisance and negligence. The Privy Council regarded three factors to be of critical significance in relation to the existence of a duty of care by the occupier, these being:

1. knowledge of the hazard;
2. ability to foresee the consequences of not checking or removing it; and
3. the ability to abate the hazard.

However the Privy Council qualified the duty of an individual to the extent that "what it is reasonable to expect of him in the circumstances" in both a physical and financial sense (Burns 1974, Gardner 1998). A reciprocal duty was also imposed on neighbours to take similar reasonable steps to protect their own interests.

CONCLUSION

Biosecurity legislation may leave landholders without protection from the externality caused by the unconstrained dispersal of local weeds. Civil tort law may provide a remedy to this problem even though it is reactive by nature: a claim for damages can only be brought for harm that has already occurred, not for potential harm. However, should a significant private nuisance action for weed spread be successful, the threat of costly litigation may be enough to encourage errant landholders to improve their weed management practices. The tort of private nuisance may therefore prove to be an effective tool for landholders to seek a remedy to harm caused by unchecked local weed dispersion.

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HERBICIDE RESISTANCE IN NON-AGRICULTURAL AREAS

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SUMMARY A survey of non-agricultural areas including roadsides, railway right-of-ways and irrigation channels was conducted across Australia to investigate the extent of glyphosate resistance in four weed species. A total of 150 windmill grass (*Chloris truncata* R.Br.) and 84 fleabane (*Conyza bonariensis* (L.) Cronquist) populations were collected from QLD, NSW, VIC, SA and WA. A total of 7% of the windmill grass and 52% of the fleabane populations contained individuals resistant to glyphosate. Of 186 populations of annual ryegrass (*Lolium rigidum* Gaudin) collected from SA, NSW and WA, 50% were found to contain high numbers of resistant individuals. Nine populations of barnyard grass (*Echinochloa colona* (L.) Link) were collected from northern NSW and three of these were resistant. Glyphosate resistance in these non-agricultural areas has the ability to spread into other areas, such as crops, and cause management difficulties elsewhere. Therefore, the high degree of resistance found in this study highlights the importance for the development and application of management strategies for these areas.

Keyword: Glyphosate, herbicide resistance, roadside.

INTRODUCTION

Glyphosate is the most widely used herbicide for weed control in Australia, in both agricultural and non-agricultural situations. While resistance to glyphosate has occurred at numerous sites in agricultural systems in Australia, it has also begun to appear in a number of non-agricultural settings including road sides, railway rights-of-way and irrigation channels. Glyphosate resistance in these non-crop areas, in addition to causing immediate impacts, has the ability to spread into other areas causing management difficulties.

Herbicide resistance in non-agricultural situations is rarely reported and little is known about the risks of herbicide resistance in these areas. Resistance in these areas is likely to be glyphosate resistance since this herbicide is the cornerstone of many control programs. The aims of the research was to discover risks of glyphosate resistance evolving on land managed by local councils, railways, transport and water authorities in Australia and other users of glyphosate. To recognize information requirements and strategies for all users of glyphosate that will reduce the risk of glyphosate resistance occurring and better manage the movement of glyphosate resistant weeds.

This paper outlines the findings of an investigation into the extent of glyphosate resistance present in non-agricultural areas across Australia, as well as identifying the information needs of users of glyphosate in non-agricultural areas.

METHODS

Physical Surveys:
Surveys were conducted across Western Australia, South Australia, Victoria, New South Wales and Queensland to collect weed species present on the roadsides, along railway right-of-ways and around buildings or irrigation channels. Four different weed species were targeted in the survey: annual ryegrass fleabane, windmill grass, and barnyard grass. Collected plants or plants grown from collected seed were tested with appropriate rates of glyphosate to identify resistant individuals.

RESULTS AND DISCUSSIONS

Physical survey
In excess of 400 samples of whole plants or seed of the four species were collected from SA, NSW, QLD, VIC and WA. Glyphosate resistance was identified in all four weed species. High frequencies of glyphosate resistance were identified in annual ryegrass and fleabane, where more than 50% of populations contained high numbers of resistant individuals. Resistance was identified in all states surveyed.

Glyphosate resistance was found to occur in all non-agricultural areas surveyed. The majority was found on roadsides, often adjacent to crops. However, resistance was also identified along irrigation channels, railway rights-of-way and around buildings, such as silos.

Table 1. Distribution and frequency of glyphosate resistant weeds found in Australia from non-agricultural areas (Malone *et al*. 2012).

Species	Location	No. collected/ No. resistant	Total	Resistant (%)
L. rigidum	NSW	75/37	186	50%
	SA	54/41		
	WA	57/15		
C. bonariensis	QLD	9-Jul	84	52%
	NSW	41/31		
	VIC	14/0		
	SA	12-Jun		
	WA	8/0		
E. colona	QLD	1-Jan	9	33%
	NSW	8-Feb		
C. truncata	Vic	65/6	150	7%
	WA	22-Jan		
	SA	6/0		
	NSW	55/1		
	QLD	2/0		

Implications
This study has demonstrated that there is a large amount of glyphosate resistant weeds in non-cropping areas (Table 1). These resistant weeds need to be controlled by other weed management techniques. Glyphosate resistant weeds evolve wherever there is intensive

reliance on glyphosate for weed control and few or no other weed management practices used. Glyphosate resistant weeds in non-agricultural areas have the potential to spread into nearby agricultural production areas and vice versa. Effective management of glyphosate resistant weeds in non-agricultural areas will reduce this risk.

As a consequence of the evolution of glyphosate resistance, and also weed species shifts caused by the continuous use of glyphosate, alternative strategies to manage weeds are required. These strategies can be non-chemical and tactics such as slashing, mowing or steaming weeds may be appropriate in some areas. However, there are areas where herbicides are the most practical choice for controlling weeds. In these areas, alternative products will be required.

Alternative herbicides for roadsides

As a consequence of the evolution of glyphosate resistance, and also weed shifts caused by the continuous use of glyphosate, alternative strategies to manage weeds are required. These strategies can be non-chemical such as slashing, mowing or steaming weeds which may be appropriate in some areas. However, there are areas where herbicides are the most practical choice for controlling weeds. In these areas, alternative products will be required.

A search was conducted for all herbicide products registered for use on roadsides or rights-of-way (Table 2). There is also a list of herbicides registered for irrigation channels (data not presented) which is essentially a sub-set of the roadside herbicides. The table combines information about weed control spectrum, impacts on other vegetation, particularly trees, and impacts on water. There are also products registered that contain mixes of these herbicides, not all of these are listed. The product label should be consulted to determine whether that specific product is registered for use.

The greatest areas of risk from roadside herbicide use due to the potential of the herbicide moving into water ways and causing damage to aquatic organisms or causing damage to roadside vegetation. Table 2 is designed as an aid for decision makers and users to choose the appropriate product to use in a specific situation. Glyphosate is listed at the top of the table as a comparison as users are most familiar with this herbicide.

Main weeds controlled: Not all herbicides are effective on all plant species. This column provides information on the species these herbicides are effective against. For most herbicides, the plant species are described as grasses or broad leaf species. The level of control will vary depending on the herbicide rate used and the size of the plant species.

Potential impact on aquatic species: Herbicides are designed to kill plants, so some will have an impact on aquatic plants and algae while some may also be harmful to fish and other aquatic organisms. The size of the potential impact depends on the concentration of herbicide and the sensitivity of the species to the herbicide. Herbicides may have a high potential to harm aquatic organisms, but only if they enter the water at sufficiently high concentrations. The risk can be decreased by not applying herbicides close to water courses.

Potential impact on nearby trees: Tree damage can occur through spray drift from herbicide application of from herbicides leaching through the soil profile. Contact herbicides, such as paraquat and glufosinate, will cause temporary damage from spray drift. Other herbicides, such as 2,4-D and glyphosate may cause more lasting damage.

Table 2. A selection (readily available) of herbicides registered for use in Australia on roadsides or rights-of-way.

Herbicide active ingredient	**Example product**	**Main Weeds Controlled**	**Potential impact on aquatic species**	**Potential impact on nearby trees**
Glyphosate	Roundup	Grasses and broadleaves	Low toxicity. Many formulations have aquatic issues	Low. Spray drift onto small shrubs/trees
2,4-D	Amidcide 500	Broadleaves	Low but varies with formulation	High from spray drift
Aminopyralid	Hotshot (+ fluroxypyr) or Grazon Extra (+ troclopyr)	Broadleaves	Moderate	High. Do not apply near trees where roots may extend
Amitrole	Amitrole T	Some broadleaves and grass	Low	Low
Bromacil	Uragan	Annual grass and broadleaf plants	Moderate	Do not apply near trees where roots extend
Clopyralid	Lontrel	Broadleaves	Moderate	Medium to high (spray drift)
Diquat	Sprayseed (with paraquat)	Annual weeds	Moderate. Diquat products are registered around water bodies	Low. Damage transient.
Fluazifop	Fusilade	Grasses – some perennial species	Low to moderate	Low
Flupropanate	TaskForce	Perennial grasses	Low	Low
Fluroxypyr	Starane Advanced	Broadleaves	Low (fish) & moderate (algae)	Medium to high (drift)
Glufosinate	Basta	Most annual weeds	Low	Low
Hexazinone	Velpar	Grasses and broadleaves	Moderate to high	Moderate
Imazapyr	Arsenal	Grasses and broadleaves	Moderate	Low
Metsulfuron	Brush-off	Broadleaves	Low	Medium
Picloram	Tordon	Broadleaves	Moderate	High. Do not apply near trees where roots may extend
Pine Oil	Bioweed	Small annual weeds	High. Do not contaminate water ways	Low
Sulfometuron	Oust	Grasses and broadleaves	Low	Medium. Higher in alkaline soils
Terbacil	Trimac (with sulfometuron)	Some annual broadleaves	Low	High. Do not apply near trees where roots may extend

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UNDERSTANDING THE ECOLOGY OF INVASIVE UNPALATABLE PERENNIAL GRASSES TO HELP IN THEIR CONTROL
The case of unpalatable perennial grasses native to central Argentina

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SUMMARY Native unpalatable perennial grasses (UPG) have been steadily invading semiarid grasslands formerly dominated by palatable perennial grasses (PPG) in central Argentina. The objective of this paper is to synthesise key aspects of the ecology of UPG, and from that to derive management practices for their control. Studies have shown that PPG have higher competitive ability than UPG. However, selective grazing of PPG reduces their competitive ability, favouring growth and seedling establishment of UPG. Once UPG attain dominance they impair seedling establishment of PPG even in the absence of grazing. UPG produce tissues with high C/N ratio, which slow down litter decomposition and nutrient release rates. They are less productive than PPG, which in combination with their low nutritive value can markedly reduce carrying capacity and livestock productivity. Current knowledge available on the ecology of UPG suggests that a key approach to their control is through allowing PPG to express their superior competitive ability. Experimental evidence from Australian native grasslands also supports that a more successful way of controlling *Nassella trichotoma* (serrated tussock, an UPG native to Argentina) in the long term is with an integrated weed management system focusing on enhancing the competition from native perennial grasses rather than repeated herbicide applications.

Keywords: Invasive species, perennial grass weeds, overgrazing, grazing management, controlled burning.

INTRODUCTION

Native grasslands in central Argentina (Lat. 36-40° S, Long. 62-66° W) experience temperate, semiarid climates. Mean annual air temperature is 15 ºC, mean annual precipitation 400 mm (30% CV), and mean annual potential evapotranspiration 800 mm. Dominant soils are Complex Calciustolls, of coarse texture. Phytogeographically, the region belongs to the Caldén District of the Espinal Province (Cabrera 1976). Originally, the physiognomy of the vegetation resembled a grassland with scattered or grouped trees and shrubs, the herbaceous layer was dominated by palatable perennial grasses (PPG; e.g. *Poa ligularis*, *Nassella longiglumis*) (Gallego *et al.* 2004), *Lama guanicoe* was the main large native herbivore, and the return period of natural fires was less than 10 years (Bóo 1990). Since introduction of livestock at the beginning of last century, the physiognomy has changed to shrubland, and the herbaceous layer has been frequently invaded by native unpalatable perennial grasses (UPG; e.g. *Nassella tenuissima*, *N. gynerioides*, *N. trichotoma*, *N. brachychaeta*) (Fernández *et al.* 2009).

Land in the region is privately owned. Presently, commercial cattle breeding is the dominant production system. Average stocking rate varies between 5 and 15 ha per breeding unit, depending on the condition of grasslands. Weaning percentage (around 60%) and meat production (10 or less kg/ha/yr) are well below potential values (Morris and Ubici 1996).

The objective of this paper is to provide a synthesis on key aspects of the ecology of UPG, and from that to derive management practices for their control.

EFFECTS OF SELECTIVE GRAZING

Native UPG were poorly represented in pristine grasslands, as demonstrated from evidence provided by soil phytoliths analysis (Gallego *et al.* 2004). Experimental research has revealed the superior competitive ability of PPG (Moretto and Distel 1997), which suggests a competitive displacement of UPG by PPG in the absence of livestock grazing. Badgery *et al.* (2005) reported similar results from a study on the competition for nitrogen between Australian native grasses and the UPG weed *N. trichotoma* (serrated tussock) at low nitrogen levels. However, selective defoliation of PPG by livestock depresses their competitive impact (Moretto and Distel 1999), and creates vegetation gaps of low competitive pressure that favour seedling establishment and growth of UPG (Moretto and Distel 1998). Under low competitive pressure UPG have shown a relatively high growth potential, despite their relatively high investment in antiherbivore defences (e.g. structural carbohydrates, particularly lignin; Distel *et al.* 2007).

Once established, anecdotal evidence suggests UPG individuals can survive for decades, as typical for many tussock-forming grasses (Lauenroth and Adler 2008). The dominance of long-lived plants causes asymmetric competition, which limits reestablishment of PPG individuals even in the absence of livestock grazing. UPG are less productive than PPG (Moretto 2009), and their low-quality litter (i.e. higher C/N ratio) decomposes and releases nutrients at a slower rate than that of PPG (Moretto *et al*. 2001, Moretto and Distel 2003). However, results of soil inorganic nitrogen availability tests suggest a relatively low capacity of UPG to cause nutrient immobilization in soil bacteria (Moretto and Distel 2002, Andrioli and Distel 2008).

Livestock show a clear preference for PPG and avoidance of UPG (Bóo *et al.* 1993, Bontti *et al.* 1999, Pisani *et al.* 2000), which can be explained by differences in plant chemistry between both groups of grasses (Distel *et al.* 2005). Moreover, the avoidance of UPG enables them to accumulate senescent biomass, further reducing their nutritional value to grazers. As a result, the invasion of UPG in grasslands formerly dominated by PPG causes a marked reduction in carrying capacity and in the production livestock products per unit of land (Morris and Ubici 1996).

ENHANCING PALATABLE GRASS COMPETITION

From the preceding background on the ecology of UPG, and considering the common expansive nature of livestock operations in rangelands and consequent high rehabilitation costs, the main inference is that the approach for their long-term control needs to be primarily based on enhancing the competition from PPG. To prevent invasion of UPG, grazing management should be planned in a way to allow PPG expression of their productive potential, reproductive capacity and competitive ability. Increased plant vigour in turn requires the maintenance of a minimum residual biomass for plant and soil protection (Badgery 2008b), and provision of appropriate rest periods for plant recovery after defoliation. This can be accomplished through the implementation of an adaptive rotational grazing system (Kothmann 2009), in combination with a flexible stocking regime (Campbell *et al*. 2006, Díaz-Solís *et al*. 2009, Distel 2011). Native Australian grasses prevented the UPG weed *N. trichotoma* from increasing in biomass, basal area and density, when rotationally grazed or when grazing was removed and fertiliser was withheld (Badgery *et al.* 2008a, 2008b). In addition, a minimum herbage mass of 2 t DM/ha and 100% ground cover prevented *N. trichotoma* seedling recruitment and as little as 0.5 t DM/ha of desirable perennial grass caused complete mortality of seedlings during the first summer (Badgery *et al.* 2008b) presumably by depleting soil moisture.

BURNING

In grasslands already invaded and dominated by UPG, recovery of PPG may, at first, need the application of a disturbance other than grazing (Distel and Bóo 1996). Because of its low economic cost and feasibility to apply over extensive areas of land, prescribed burning may represent a potential valuable tool. UPG are more sensitive to fire than are PPG, since the former accumulate much more senescent biomass than the latter (Peláez *et al.* 2003). Hot fires have been shown to kill many more individuals of UPG than those of PPG, and to reduce or increase basal area of surviving plants, respectively (Bóo *et al.* 1996, Guevara *et al.* 1999). Successful recovery of PPG may, in addition (to prescribed burning), need the stocking rate and rotation of grazing to be controlled to favour establishment and growth of PPG. Since burning can also stimulate UPG (Badgery 2003), enhanced competition from PPG is necessary to suppress both the regrowth of surviving plants and recruitment of new individuals of UPG. The initial density of UPG is therefore important.

CONCLUSION

In native grasslands of central Argentina, heavy selective grazing of PPG reduces their superior competitive ability thereby establishing the potential for UPG invasion. Once established, UPG individuals can survive for long periods of time, causing a marked reduction in carrying capacity and in livestock production per unit of land. Appropriate burning and grazing management to enhance the competition from PPG may represent a sound alternative for restoration of PPG in grasslands invaded by UPG. Experimental evidence from Australian native grasslands also supports that a more successful way of controlling *N. trichotoma* in the long-term is with an integrated weed management system focusing on enhancing the competition from native perennial grasses rather than repeated herbicide applications and controlling isolated mature plants with spot spraying or chipping before they increase in density.

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BENEFITS OF NATIONAL WEED INITIATIVES FOR NSW: SUCCESSES AND FUTURE OPPORTUNITIES[A]

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SUMMARY Effective weed management is most successfully achieved when done in an integrated and coordinated manner. This applies to on-ground action, i.e. implementing weed control, as well as to policy, planning and resourcing. The partnerships and relationships that underpin weed management are equally as important as the 'on-ground' activities. Like weeds, these foundational partnerships should know no boundaries. To achieve landscape-scale outcomes for the protection of biodiversity and production assets, it is critical to integrate local, regional, state and national partners in planning and implementation. This paper demonstrates how national initiatives and the high level plans, strategies and frameworks that result from them, have resulted in stronger partnerships and improved on-ground weed management. We use examples from the last 10 years of the Weeds of National Significance (WoNS) initiative to outline the benefits of collaborative weed management in New South Wales. We then explore how local, regional and state partners in New South Wales can benefit from participation in future national weed management initiatives, including national surveillance, weed spread prevention and WoNS opportunities.

Keywords: Coordination, eradication, surveillance, early detection, National Invasive Plant Surveillance Framework, Weeds of National Significance.

INTRODUCTION

Cooperative management and strong, comprehensive partnerships are foundational components of strategic weed management efforts. Just as effective control methods are fundamental to success, so too is the need to engage in cross-tenure partnerships that include all affected parties and allow them to align their goals and priorities. In New South Wales, there are multiple 'layers' of weed management policy, planning and action: Community and local government, regional weed committees and Natural Resource Management groups, and state-level entities all interact in the process of managing weeds. These groups work together to ensure that long-term goals align, however given the large number of groups, and limited resources, many groups may not have the time or ability to coordinate across all partners. Thus, an overarching coordination role that brings together weed management efforts at several levels can be beneficial.

The New South Wales government supports regional and state weed coordinators, and also partners with the Australian Government to contribute to national weed coordination through the Weeds of National Significance (WoNS) program. The WoNS initiative is a joint effort by all governments to reduce the impact and prevent the spread of some of Australia's worst weeds. National strategic plans are in place for 32 WoNS,

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and national coordinators (hosted by State and Territory agencies and jointly funded by the Australian Government) work with weed managers at all levels to implement WoNS strategic plans. New South Wales is a major player in the WoNS initiative and has hosted 11 of the 32 WoNS coordination projects. Since 2004, the Department of Primary Industries has hosted: the aquatic weeds alligator weed (*Alternathera philoxeroides* (Mart.) Griseb.), cabomba (*Cabomba caroliniana* A.Gray), salvinia (*Salvinia molesta* D.S.Mitch), water hyacinth (*Eichornia crassipies* (Mart.) Solms) and sagittaria (*Sagittaria platyphylla* (Engelm.) J.G. Smith); and the serrated tussock (*Nassella trichotoma* (Nees) Hack. Ex Arechav.); Chilean needle grass (*Nassella neesiana* Trin. & Rupr.) Barkworth; and fireweed (*Senecio madagascariensis* Poir.) coordinators. Since 2005, the Office of Environment and Heritage has hosted the bitou bush and boneseed (*Chrysanthemoides monilifera* (L.) Norl.), asparagus weeds (*Asparagus* spp.) and brooms (*Cytisus scoparius* (L.) Link and *Genista* spp.) coordinators. To facilitate implementation of WoNS strategic plans, coordinators engage with and support local, regional and state weed initiatives and encourage partnerships to achieve WoNS actions and provide flow on benefits for other weeds and broader weed management (Cherry *et al.* 2012).

In addition to WoNS coordination roles, the Australian Government, in partnership with the States and Territories, support a National Weed Spread Prevention Coordinator, who facilitates the National Weed Spread Prevention Initiative (NWSPI). This initiative was established in 2011 to progress national action on early detection and weed spread prevention goals, as outlined in the Australian Weed Strategy (AWS) and the Intergovernmental Agreement on Biosecurity (IGAB). New South Wales is a partner in implementing the AWS and IGAB: The New South Wales Invasive Species Plan and Biosecurity Strategy are aligned to the goals in these national initiatives.

The NWSPI seeks to improve national capability for weed prevention and early detection by improving communication and knowledge sharing between stakeholders. The initiative has worked with States and Territories to determine what national systems and structures could assist in improving jurisdictional rapid response capabilities. This engagement has resulted in the development of industry-wide weed surveillance protocols, the establishment of new nation-wide discussion groups on weed prevention and rapid intervention, and the National Invasive Plant Surveillance Framework (NIPSF). The Framework aims to strengthen Australia's post-border capacity for early detection and rapid response to new invasive plant incursions and range expansions of existing invasive plants.

This paper highlights achievements from these national initiatives, which focus on developing plans and facilitating partnerships to collaboratively address landscape-level weed issues. We then explore possible opportunities for New South Wales weed managers to engage in these initiatives in the future.

NEW SOUTH WALES SUCCESSFUL PARTNERSHIPS

National initiatives and the plans, strategies and frameworks that result from them, are high level bureaucratic documents that, without careful implementation, have the potential to result in negligible improvement to on-ground weed management. The legacy of national coordination has been in providing a conduit for information sharing and collaboration that ensures these high level plans reflect on ground needs, and that action in these plans translates into tangible on-ground outcomes.

Collaboration in the WoNS initiative provides long-term benefits for New South Wales. Joint partnerships have led to long-lasting programs for eradication (boneseed, parthenium (*Parthenium hysterophorus* L.), parkinsonia (*Parkinsonia aculeata* L.) and containment (bitou bush, lantana (*Lantana camara* L.), gorse (*Ulex europaeus* L.), Chilean needle grass and cabomba) of WoNS in New South Wales, minimising future impacts. WoNS coordinators also support New South Wales state programs, for example for bitou bush, fireweed, serrated tussock and aquatic weeds) and work together with regional and local groups to support community efforts, for example Willow Warriors). WoNS partnerships link weed researchers and managers and encourage cooperative research on a national and international scale. For example, over 18 biological control agents for eight WoNS are active in New South Wales, and partnerships support continued research and redistribution of these agents across the state. WoNS coordinators also support joint awareness initiatives, such as *NSW No Space for Weeds*, and the development of education resources, for example, *Weeds Attack!* a web-based tool to teach primary school students about weed impacts developed with the New South Wales Department of Education (see Cherry *et al.* 2009).

An overarching goal for WoNS partners is to integrate and align national, state, regional and local plans to create a legacy that allows strategic weed management actions to continue, with all levels of government supporting agreed priorities (Cherry *et al.* 2012). In New South Wales, WoNS coordinators have worked with all partners to align WoNS actions and goals to the New South Wales Invasive Species Plan, regional catchment action plans, regional weed action plans, and the New South Wales Biodiversity Priorities for Widespread Weeds project, which is an overarching threat abatement strategy that works to reduce impacts of widespread weeds on biodiversity across New South Wales (Turner *et al.* 2013). These are in turn aligned to the AWS and IGAB, as noted above. Thus activities that achieve regional or state goals will also contribute to achieving national goals, and may be eligible for a greater number of funding opportunities from all levels of government.

National coordination through the National Weed Spread Prevention Initiative has also allowed integration of national and New South Wales weed efforts. This initiative has improved communication between partners involved in weed spread prevention and early detection, both within New South Wales and across borders. Workshops with key partners such as industry bodies, herbaria, and primary production and conservation agencies have provided opportunities to better understand the individual motivations for involvement in a national surveillance system, and have allowed scoping of a national system that will align to the needs of all partners. The initiative has increased commitment from industry to weed surveillance, highlighted the contributions of herbaria to national surveillance efforts, and developed a framework to align surveillance approaches nationally. The National Invasive Plant Surveillance Framework includes specific actions that are designed to facilitate and extend on actions under the New South Wales New Weed Incursion Plan (NSW DPI 2009). An example of this is the recognition within the framework that herbaria play a critical role in the identification, verification, curation and reporting of invasive plants. As in the New South Wales New Weed Incursion Plan, actions are also included in the framework to facilitate adequate and ongoing support to ensure critical herbaria services are maintained and/or expanded to improve capability for early detection of new weeds in New South Wales.

FUTURE OPPORTUNITIES

The successes detailed above for the original 20 WoNS are continuing, and strategic plans for these WoNS were revised in 2012 to set national direction through to 2017. In addition, there are 12 new WoNS strategic plans that also present opportunities for the future. These new and revised plans were agreed by all levels of government, and thus actions in these plans reflect national and jurisdictional priorities. National coordination of the 12 new plans began in 2012. While continued support for national coordinators is subject to resource availability, all new plans include as high priority actions: 1) support of a national coordination role; and 2) development of a national management group, to engage all partners in strategic plan implementation.

The 12 new plans encompass 45 weeds (3 cover multiple species: 27 cacti, 6 asparagus weeds and 3 brooms), and at least 40 of those impact New South Wales, or may in the future. Many opportunities exist for New South Wales to benefit from participation in new WoNS activities. All 12 plans have overarching high-level objectives, and partners in New South Wales can develop actions to address these objectives in ways that achieve local, regional and state priorities. These objectives include that: a) invasion vectors, sources and pathways are identified and managed to prevent or reduce spread; b) surveillance and response mechanisms ensure timely detection of infestations; c) priority outlier infestations are contained or eradicated and spread from core infestations is prevented; d) priority assets are benefitting from long term strategic weed control programs; e) integrated weed management practices are improving natural resource condition and sustainable production; f) best practice management delivers efficient, effective and long-term control; g) capability and motivation for weed management is enhanced by education and awareness; and h) research priorities are identified, promoted, addressed and results are used to improve management.

While the WoNS initiative is largely a species-specific approach, actions undertaken to achieve WoNS objectives will be relevant to many other weeds. Holistic actions towards these objectives, and maintaining the legacy of existing WoNS achievements, will help progress national weed management efforts and cement partnerships from national to local levels to collaboratively achieve AWS and IGAB goals, as well as implement the NIPSF. The National Weed Spread Prevention Initiative also provides a mechanism to continue this legacy and value-add to existing efforts. Sustained partnerships, coordination, and communication will allow continued alignment of weed management objectives across all levels, and strengthen the ability of partners to deliver the best possible cross-landscape outcomes. National initiatives such as WoNS and NWSPI provide a strong framework to deliver such outcomes. The challenge is to ensure a coordinated approach is maintained in future, that continues to connect high level policies and plans to on-ground action. This will ensure on-ground actions are strategic and meaningful, and will build on the significant investment in weed management over the past decade. Collaborative partnerships established as part of these national initiatives may provide a mechanism for this connection in the future, both for New South Wales and nationally. Please visit the Weeds of National Significance site online (WoNS 2013) for WoNS strategic plans and related resources.

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SOME WEEDS HAVE NO BOUNDARIES
What are the next steps we need to take with species that jump the fence?

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SUMMARY Over 70% of current noxious weed declarations have been, and in many cases still are used by people, in gardens, aquaria, for soil conservation and even as food. People sell them, grow them in gardens, fields and aquaria, care for them, use them for protection for themselves, their animals and their land. This results in positive impacts for those who grow these plants. Unfortunately this also brings these people into conflict with others who want to stop these plants 'jumping the fence' and growing as weeds somewhere else. For this reason such plants are variously known as contentious, commercial or conflict species (Johnson 2012).

All weedy plants have at least two characteristics in common: they have significant (negative) impacts, and are invasive in new environments. Said another way, such plants have no boundaries, or at least effectively appear to get around the boundaries that people put in place to try and stop them. This paper identifies a selection of recently naturalised conflict species that have jumped the fence in New South Wales. Some of these are causing emerging problems, at the moment. The paper then focuses on three case studies: *Anredera cordifolia* (Ten.) Steenis (Madeira vine); *Arundo donax* L. (Giant reed); and a *Musa* species (ornamental banana). It examines a range of biological, impact and weed risk management assessment characteristics for each, before recommending proposed management directions for these and other conflict species.

Keywords: Conflict, commercial, positive, negative, impacts.

INTRODUCTION

There are a large number of reasons that plant species are introduced into new environments, for example for the production of human and animal foods, as a source of edible oils, as garden or aquaria plants, for soil conservation purposes and for herbal and medicinal purposes, among many others. Conflict may occur when these species 'jump the fence' and naturalise into surrounding environments, causing negative (weedy) impacts and becoming known as contentious, commercial or conflict species (Johnson 2012). The conflict surrounding these species is not easily resolved, particularly when the positive and negative impacts are experienced by different sectors: for example primary producers and consumers often benefit or experience positive impacts from the introduction of a new plant species but, upon naturalisation and spread, the negative impacts of a weedy plant are borne by the environment and custodians for its care (Bennett and Virtue 2004, Anon. 2006).

Examining just two of the above categories, these being human foods and edible oils, more than 100 species used for these purposes have naturalised in New South Wales (NSW, RBG&DT 2013, Johnson unpublished). The majority of these plant introductions have resulted in overwhelmingly positive impacts, with only nuisance weedy impacts experienced. Having said this, some species including European olive (*Olea europaea* L. subsp. *europaea* L.), some blackberry (*Rubus*) species and strawberry guava (*Psidium* *cattleyanum* var. *cattleyanum* Sabine), a particular problem on Lord Howe Island, also have significant negative impacts. Others plant species such as the passionfruit (*Passiflora*) species and taro (*Colocasia esculenta* (L.) Schott) may become weeds in future (Johnson unpublished).

It is likely that plant naturalisations will continue in NSW. Since European settlement in 1788 (226 years), at least 1749 taxa have been introduced into new areas of the state and have naturalised: this includes species exotic to Australia; exotic to the State; and native to the state but exotic to their new area of naturalisation, J. Hosking, personal communication January 2013). The overall average naturalisation rate (7.7 species per year) hides what has been an increased recording rate of 18.7 species per year since the year 2000, probably largely a result of increased research into this problem (Hosking *et al.* 2003, 2007, 2011; Johnson *et al.* 2013).

Management of at least some of the new and emerging conflict weed problems is needed, as highlighted by the cascading Australian Weeds Strategy (AWS 2006), the NSW Invasive Species Plan (NSW DPI 2008) and the NSW New Weed Incursion Plan (NSW DPI 2009). Decision support systems have been developed to identify and prioritise these species, for example Johnson (2009a, b) and Johnson *et al.* (2010). Concurrently, at least three industries have taken steps to risk assess the plants they sell, that is the nursery and garden (Kachenko 2012) and aquarium (Champion *et al.* 2008) industries, and those involved in fixing salinity problems (Stone *et al.* 2008). Many other industries have not yet formally recognised the problems that plants they introduce and grow can cause someone else.

This paper lists a selection of recently naturalised conflict species that have jumped the fence. At the moment, only some of these species have been recognised as emerging threats. The paper then examines three species that are increasing in prominence, examining the biology, impacts and weed risk management assessment results for each. Finally, it recommends management directions for government, industry and the broader community for these and other conflict plants.

PLANT TAXA RECORDED AS NATURALISED IN NSW DURING 2000-2012

Forty of the 243 taxa that have been recorded as naturalised during 2000-2012 have been identified (Table 1). These species have been introduced for a variety of purposes (for positive impacts), although use in gardens and street plantings predominates. Together these species represent what may be the most significant new and emerging weed species of tomorrows' environmental values in NSW (demonstrating negative impacts). Accordingly, 17 of these taxa have been assessed with the NSW Weed Risk Management (WRM) and are declared noxious in areas, or across the state. The remaining species, as well as the nearly 200 other taxa not listed but that have been recorded as naturalised since the year 2000 (and many plant taxa naturalised before this time) need both preliminary, Johnson *et al.* (2010), and if necessary, full WRM assessment (Johnson 2009a, b).

Table 1. A selection of recently recorded naturalised plant taxa in New South Wales that have both positive and negative impacts, that is are conflict species. Information is largely drawn from Hosking *et al.* (2003), (2007), (2011) and Johnson *et al.* 2013. Only natural ecosystems that could be invaded are listed: no assessment of primary production systems or community/cultural assets has been made.

Plant species	**Probably used for**	**Ecosystems potentially invaded**
Berberis lomariifolia	Ornamental shrub	Wet and dry sclerophyll forest
Broussonetia papyrifera	Fibre (traditional source)	Forest
Bryophyllum daigremontianum and *B. × houghtonii*	Ornamental succulents	Forest, woodland and grassland
Cecropia species	Ornamental trees	Rain and sclerophyll forests
Celtis sinensis	Shade and street ornamental tree	Rainforest and riparian areas
Cylindropuntia rosea	Ornamental cacti	Woodland and grassland
Deutzia crenata	Ornamental shrub	Forests and woodland
Echinochloa polystachya	Ponded pasture animal forage grass	Riparian and wetland areas
Heteranthera reniformis	Floating wetland/aquatic ornamental	All freshwater areas
Hieracium aurantiacum subsp. *carpathicola*	Ornamental herb	Woodland and grassland
Hydrocleys nymphoides	Emergent wetland/aquatic ornamental	All freshwater areas
Hymenachne amplexicaulis	Ponded pasture animal forage grass	Riparian and wetland areas
Iris species incl. *Iris foetidissima*, *I. laevigata* and *I. virginicus*	Ornamental herbs	Riparian and wet areas
Jacaranda mimosiifolia	Shade and street ornamental tree	Forest and disturbed areas
Jasminum polyanthum	Ornamental vine	Forest
Koelreuteria formosana	Ornamental tree	Forest
Ludwigia repens	Submerged wetland/aquatic ornamental	Disturbed shallow freshwater areas
Lygodium japonicum	Ornamental fern-like vine	Riparian areas
Melastoma malabathricum	Ornamental tree	Forest
Mesembryanthemum guerichianum	Ornamental succulent	Grassy woodland
Miconia calvescens	Ornamental shrub/tree	Rain and sclerophyll forest
Musa species	Ornamental and floriculture shrub-like monocot	Rain and sclerophyll forests
Nassella tenuissima	Ornamental grass	Grassy woodland
Orbea variegata	Ornamental succulent	Woodland
Phoenix canariensis	Ornamental tree	Woodland and forest
Pinus species incl. *P. contorta, P. halepensis* and *P. patula*	Forestry timber and ornamental trees	Woodland and forest
Rhaphiolepis umbellata	Ornamental tree	Woodland and forest
Rhododendron ponticum	Ornamental shrub	Forest and woodland
Rubus species incl. *R. alceifolius, R. niveus* and *R. rugosus*	Fruit	Forest, woodland and grassland
Schinus terebinthifolius	Shade and street ornamental tree	Forest and woodland
Spartium junceum	Ornamental shrub	Forest and woodland
Tabebuia species	Shade and street ornamental trees/shrubs	Forest
Triadica sebifera	Shade and street ornamental tree	Forests and riparian areas

THREE PLANT TAXA INCREASING IN PROMINENCE

A range of biological, impact and weed risk management assessment characteristics of three taxa that are increasing in prominence is presented (Table 2) and summarised below.

Anredera cordifolia (Madeira vine)

The most widespread of the three taxa, *Anredera cordifolia* (Ten.) Steenis (Madeira vine), was named as a Weed of National Significance (WoNS) in 2012 because of its significant negative impacts on plant and animal biodiversity, on rainforest ecosystem structure and other effects. This largely vegetatively reproducing perennial vine species was widely used across eastern NSW as an ornamental, was known to have naturalised in Queensland well before 1883 (Bailey 1883) and probably in NSW before 1900; where it was declared noxious in 3 Sydney areas, initially in 1920 (Johnson 2013). It is likely that very little of the species is now sold: this is likely to be legislated in the near future similar to all WoNS species which are no longer to be traded or distributed.

The NSW WRM assessment for this species resulted in a "Manage weed Protect priority sites" category. The principles recommended for management of this species (Johnson 2009a, b) are (in summary) as follows:

- surveillance and mapping to locate infestations;
- identification of key assets that may be affected;
- control in close proximity to these key assets to significantly reduce weed density;
- limits on movement and sale;
- prevention of spread from cultivated plants near key assets;
- monitoring current distribution with respect to key assets; and
- research and development of integrated weed management (IWM) practices and then promotion of the same to landholders.

Arundo donax (Giant reed)

Again widespread, but not yet recognised widely as an invasive threat, *Arundo donax* L. (Giant reed) has long been known as 1 of 100 of the worlds worst invasive species (GISD 2013). In aquatic situations: it aggressively competes with native biodiversity (including trees); significantly increasing water use and removal; slows water movement; and prevents human access. This perennial tall grass species is spread in floodwaters by broken stem and rhizome pieces: large floating rafts of such material in floodwater are known to cause substantial infrastructure damage. The species has long been promoted and used for a range of soil conservation, shelter/shade and fibre purposes, and more recently proposed as a potential biofuel (Williams and Biswas 2010).

The NSW WRM assessment for this species resulted in a "Contain spread" category. The principles recommended for management of this species (Johnson 2009a, b) are (in summary) as follows:

- surveillance and mapping to locate infestations;
- control to significantly reduce weed density;
- prevention on entry and restrictions on movement and sale;
- prevention of spread from cultivated plants; and
- monitoring of current distribution.

Table 2. A range of biological, impact and weed risk management assessment characteristics of three plant taxa that are increasing in prominence in NSW.

Species/Characteristics	***Anredera cordifolia* (Madeira vine)**	***Arundo donax* (Giant reed)**	***Musa* species (Ornamental**

			banana)
Family	Basellaceae	Poaceae	Musaceae
Similar species	Other weedy and native vine species	*Phragmites australis* (a native)	Other commercial banana species
Growth form	Vine/climber with stems up to 20 m long	Giant grass to 6 m high	A shrub/tree 2-9 m high (actually a monocot)
Lifecycle and dispersal unit	Perennial producing almost no seed but copious numbers of tubers from aerial parts of the vine.	Perennial species reproduces vegetatively (underground) from intact rhizomes, or by broken rhizome and stem pieces.	Perennial with its true stem (a corm) below ground. Commercial species reproduce vegetatively. Weedy species and hybrids reproduce by viable seed in fruit.
Dispersed by	Humans (ornamental and dumping of garden waste), water/floodwater and animals.	Humans and floodwater.	Humans and flying animals.
Primary –ve impacts	Very significant (50-100%) reductions in establishment and growth of plants/animals in native ecosystems, vines physically restrict movement, some toxic affects suggested on animals and profound affects on biodiversity, seriously degrading rainforest ecosystems	Reduces/eliminates establishment and growth of native plant and animal species, aggressively competes with vegetation including trees, high water use species, essentially impenetrable to human movement and slows water flow, build up in floodwaters damages critical infrastructure including bridges and increases mosquito habitat.	May reduce native species establishment and growth of native species, visual degradation of landscape and host of a range of invertebrate pests and pathogens damaging to commercial *Musa* species.
Primary +ve impacts	Ornamental and shade/shelter	Range of purposes including soil conservation, fibre, biofuels, shade/shelter/crop protection, …	Ornamental

Table 2. Continued.

Current distribution across NSW		All of NSW east of the western plains, excluding the Central Tablelands but including the North West Plains	Coastal and Tableland areas, North West Slopes, South west and Far south west plains	Far North Coast, e.g. Nimbin, Murwillumbah, Tumbulgum and Lismore.
Weed Risk Management assessment	Weed Risk	456 (very high)	157 (high)	23 (low)
	Feasibility of Control	91 (low)	15 (high)	3 (very high)
	Management category	Manage weed Protect priority sites	Contain spread	Monitor Protect priority sites
Key/useful references		Vivian-Smith *et al.* (2009).	McWilliams (2004), and Williams and Biswas (2010).	OGTR (2008), Peasley (2012) and Nimbin Seeded Banana Working Group personal communication (2012).

***Musa* species (ornamental banana)**
The identity of the ornamental banana that is increasingly naturalised in areas of the Far North Coast of NSW is unclear, but is perhaps closest to *Musa acuminata* Colla, a probable early parent of commercially grown (edible) bananas. It is also important to note that the taxonomy of species in the genus *Musa* is, at best, unclear, and complicated by extensive hybridisation from a long history of cultivation (OGTR 2008). The fruit of this species produce seeds to 3.5 mm in diameter that appear to be dispersed by flying animals, particularly along riparian areas and into rainforest. Most recently, concern about the species focussed on its ability to possibly host banana bunchy top virus (Peasley 2012), a major threat to cultivated *Musa* species (edible, floricultural and ornamental).

In addition, the species has weedy impacts and the NSW WRM assessment for this taxa resulted in a "Monitor Protect priority sites" category. The principles recommended for management of this species (Johnson 2009a, b) are similar to those for *Anredera cordifolia*, excepting the research, development and promotion of IWM practices. This is appropriate given that the species is not yet widespread and is also easily managed.

PROPOSED MANAGEMENT DIRECTIONS

Many cultivated plant species jump the fence and naturalise. The positive impacts, or utility of these species is often compromised when this occurs, and some species, rather than being just of nuisance value, have significant negative impacts, often on environmental values. Over 70% of currently noxious weed declarations have been and/or still are used by humans, and are conflict species.

Based on the principles for management that resulted from the NSW WRM assessments above, and the current organisational structures within NSW, recommended management of naturalised infestations of the three taxa discussed in Table 2 (and potentially many other conflict species) may include:

- **State Government**
    - **NSW DPI –** prevention on further entry (where desirable); legislation to ensure control over sale and movement; legislation to enable management including the examination and application of innovative instruments and mechanisms; research and development for integrated weed management practices (where relevant); and production of educational material and resources;
    - **NSW Office of Environment and Heritage** (OEH) – identification of newly naturalising plant species; control of infestations to reduce weed density; and identification of key assets that could be affected (including with Local Government);
- **Local Government –** surveillance and mapping of current infestations; identification of key assets that could be affected (including with NSW OEH); control of infestations to reduce weed density; enforcement of controls over sale and movement; monitoring current distribution; and production of local educational material and resources (as needed);
- **Industry, including growers and funding bodies –** industry planning to prevent or minimise naturalisations; reporting of current/new infestations; control of infestations to reduce weed density; prevention of spread from cultivated plants; funding and support of research and development for integrated weed management practices; and weed risk management assessment of new plant species;
- **Other landholders –** control of infestations to reduce weed density; and
- **The general community –** voluntary control of infestations; and reporting on changes in current distribution.

Overall, containment of new and emerging species, particularly those that are conflict species, appears to be one of the best ways forward (Grice *et al.* 2010). Since voluntary arrangements alone appear to be insufficient to contain such species (Grice *et al.* 2010), and codes of practice based on voluntary measures represent little improvement (Walton 2003), it is likely, without significant change in the legislative landscape, that continued legislative instruments such as those outlined above will be needed. Having said this, conditional licenses/permits (Clarkson *et al.* 2010) have been discussed as an additional instrument that may be implemented easily.

There are potentially a larger number of mechanisms by which to manage new and emerging (and conflict) weeds: a complement of which have been extensively examined (Arcioni 2003). The NSW government has traditionally chosen to legislate using noxious weeds powers, for example Johnson (2013), recognising that both market forces and common law do not result in the most effective outcomes, for example Blackmore (2011), although note the later examination by Blackmore (2013). A range of more innovative and theoretical mechanisms have recently been proposed: these operate through both financial responsibility and enabling instruments for industry proponents (Le Gal 2011), some of which are similar to approaches proposed by others, for example Clarkson *et al.* (2010). Consideration of these mechanisms and instruments, particularly weed inspections upon property transactions (Martin 2008), needs further investigation as NSW moves away from specific biosecurity risk legislative instruments, for example the *Noxious Weeds Act 1993*, to a future overarching *Biosecurity Act*. Only in this way can both governments and industry help stop plants from jumping the fence and becoming our next weeds.

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GENETIC ANALYSIS OF NATIVE AND INTRODUCED POPULATIONS OF THE AQUATIC WEED DELTA ARROWHEAD
Implications for biological control in Australia

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SUMMARY *Sagittaria platyphylla*, an emergent aquatic plant introduced from the southern USA during the early 1900's, is now widely established in south eastern Australia where it invades and chokes shallow waterways. In 2010, a research program was initiated to investigate the prospects for initiating a biological control program against *S. platyphylla* in Australia based on 1) the availability of highly damaging, specific natural enemies within the native range and 2) the likelihood of those being effective biological control agents should they be released into Australia. In addition to extensive and systematic surveys of the natural enemy fauna of *S. platyphylla* across much of the native range, a concurrent molecular study was undertaken. Genetic analyses using AFLPs were used to assess populations from the invaded Australian range for comparison with populations in the southern USA. The primary purpose of the genetic study was to determine if the origins of the Australian populations could be identified so as to target the search for prospective biocontrol agents to populations with the closest genetic match to Australian genotypes. Secondly, the genetic study revealed important information about the extent of genetic variation within Australian populations, which is crucial information necessary to direct future biocontrol research efforts.

Keywords: Delta arrowhead, *Sagittaria platyphylla*, genetic diversity, biological control.

INTRODUCTION

Sagittaria platyphylla (Engelmann) J.G.Smith (delta arrowhead) is a perennial, aquatic herb of the Alismataceae family. The species is native to North America where it is primarily distributed in south central USA (Godfrey and Wooten 1981), occurring in swamps, margins of lakes and ponds, sluggish streams and wet ditches (Keener 2005). The history of introduction of delta arrowhead into Australia is not well understood. Botanical and Zoological Society records indicate that *Sagittaria* species (S. *sinensis* and *S. montevidensis*) were being used as ornamental pond plants in the late 1880s but the utilization of *S. platyphylla* didn't become apparent until the 1930s when it was widely promoted as an aquarium plant (NLA 2013). It was first reported as naturalized in Brisbane in 1959, northern Victoria in 1962, New South Wales in 1964, South Australia in 1980 and Western Australia in 1999 (Adair *et al.* 2012 and references therein).

Delta arrowhead has become a serious weed throughout the irrigation regions of south-eastern Australia. It can rapidly invade shallow drains and irrigation channels, forming dense monocultures that impede water flow and damage irrigation infrastructure (Chapman and Dore 2009). In natural waterways, extensive infestations threaten native biodiversity, impede the movement of native fish and provide habitat to populations of European carp (Chapman and Dore 2009). Due to the high economic costs to agriculture and serious threats to Australian biodiversity, delta arrowhead was declared a Weed of National Significance in 2012.

What makes delta arrowhead such a highly successful invasive species? Firstly, plants produce enormous quantities of seed (achenes) from spring through to late autumn, which are buoyant and disperse long distances downstream. Secondly, plants also reproduce vegetatively via stolons, facilitating the rapid expansion of newly-established populations. Thirdly, underground storage organs (tubers) are produced in abundance during autumn, enabling populations to survive adverse weather conditions. These tubers, plus the submersed rosette form of the plant, often escape damage from contact herbicides, hence repeated applications at high dose rates are required for effective management. The control of delta arrowhead in sensitive aquatic habitats such as billabongs and wetlands is particularly problematic. While herbicide application remains the major component of current management, the risk of generating herbicide resistance in delta arrowhead is of concern. In another alismataceous weed, *Sagittaria calycina* Engelmann, herbicide resistance is already reported in 35% of *S. calycina* accessions in NSW rice crops (Cother 1999).

BIOLOGICAL CONTROL

In order to constrain the expansion and impact of delta arrowhead, studies were initiated in 2009 to investigate the potential for classical biological control utilizing natural enemies from the weed's native range. As very little was known about the phytophagous flora and fauna associated with delta arrowhead in the USA, extensive field surveys were conducted between 2010 and 2012. A total of 19 insect species were identified including leaf-feeding moths, flower and bud-feeding flies and plant-sucking bugs. The most common and abundant insect encountered was the weevil, *Listronotus appendiculatus* (Boheman), the larvae of which feed within the fruits causing significant reductions in achene production. A further two *Listronotus* species (*L. sordidus* (Gyllenhal) and *L. frontalis* LeConte), were collected from the crowns, roots and tubers and are of particular interest due to their potential capacity to damage carbohydrate storage organs and growth apices leading to plant death. Twenty-nine fungus species were isolated from leaf spot lesions however these were generalist pathogens or secondary invaders with no potential for biological control (Adair *et al.* 2012). In contrast to the USA, Australian populations were relatively free from attack by herbivorous insects or pathogens. This lack of herbivore pressure may explain the higher reproductive capacity and hence invasiveness of Australian plants. Further studies on the impact and feeding preferences of the three weevil species are required to fully assess their potential for release into Australia.

GENETIC ANALYSIS

The genetic analysis of both native and introduced populations of an invasive species is a critical step in the development of a new biological control program (Burdon and Brown 1986). Identification of the source of invasive populations can facilitate the search for appropriate biocontrol agents, as natural enemies from populations with which they co-evolved tend to be more damaging (Goolsby *et al.* 2006). Furthermore, determining the degree of genetic variation of introduced populations may provide insights into the likelihood of success of a potential biocontrol project (Nissen *et al.* 1995). The most successful biocontrol projects have been against clonal species with minimal genetic variability (Burdon and Marshall 1981).

The genetic study of delta arrowhead was conducted using Amplified Fragment Length Polymorphism (AFLP) procedures as described in Vos *et al.* (1995). Leaf samples were collected from 34 USA and 22 Australian populations, providing a good coverage of the known distribution. Unfortunately samples could not be collected from central Mexico, the most western distribution of the species' native range. The analysis of the AFLP data was made using Population Graphs (Dyer and Nason 2004), which uses a graph-theoretic framework to investigate the genetic relationships between interacting populations. Each sampled delta arrowhead population is represented as a node in the network graph with node diameter indicative of within population genetic variation, lines connecting nodes indicating populations that are not significantly genetically differentiated while line length represents among-population genetic variation (Dyer and Nason 2004).

The network graph (Figure 1) indicates that high levels of genetic diversity occur within both the native and introduced populations and that a distinct separation is also evident between Australia and the USA. Furthermore, Australian genotypes appear to consist of two main groups; a northern (mostly NSW and Queensland populations) and southern (mostly Victoria and South Australia). The high levels of genetic diversity seen in Australian populations, along with the multiple (fourteen) connection points between the USA and Australia suggests that delta arrowhead may have been introduced more than once. Sexual reproduction appears to play an important role, as cross-pollinating species usually have higher levels of genetic diversity than those reproduced clonally or by self-pollination (Ward and Jasieniuk 2009). The large genetic distance between the native and introduced populations was unexpected. One probable explanation could be that the true source population(s) were not included in this study. Or, an alternative scenario is that through cultivation by the ornamental and aquaria trade, novel genotypes have been created which are now genetically distinct from those found in the native range.

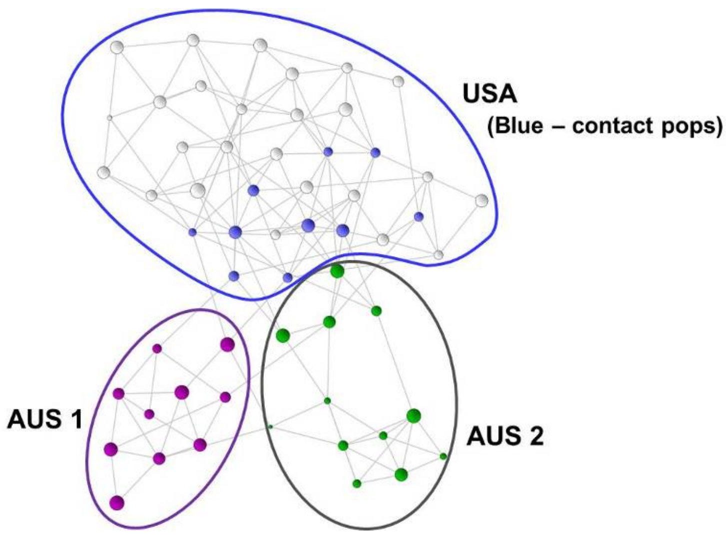

Figure 1. Population network graph of USA (circled in blue) and Australian (AUS 1 and AUS 2) populations. Blue nodes represent USA populations with links to Australian populations.

IMPLICATIONS FOR BIOLOGICAL CONTROL

Some of the most successful biological control programs worldwide have been against aquatic weeds, not because of the aquatic environments they inhabit, but because of their mode of reproduction being mainly clonal. The genetic variation within invasive clonal species makes them highly susceptible to biological control if a highly adapted, damaging natural enemy is released. Delta arrowhead however, is an exception. It has both clonal and sexual reproduction, and the introduction of multiple genotypes from across the native range has facilitated the large amount of genetic variation seen in Australian populations.
However, this does not mean that the chances of success for the biocontrol of delta arrowhead will be low. For example, invasive skeleton weed, *Chondrilla juncea* L. in Australia consisted

of three distinct genotypes, but not all were invasive. An understanding of the weed's population genetics enabled scientists to target the most invasive genotype using a highly-adapted rust fungus, resulting in successful control and an economic benefit estimated at $1.426 billion (Cullen 2012). While the invasiveness of the different Australian genotypes hasn't been investigated, there is some evidence to support this. For example, delta arrowhead was first recorded in Brisbane in 1959 and in Victoria in 1962, yet the populations in Victoria have rapidly expanded while those in Brisbane have not. Our challenge will be to find natural enemies that are highly damaging to those south-eastern Australian genotypes, and we should target our search to the USA populations with the closest genetic match.

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NO BOUNDARIES FOR NRM ON THE FAR SOUTH COAST

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SUMMARY A comprehensive 2007 survey of weed incidence and prevalence along the Bega Valley Shire coastline identified key weed threats, factors promoting weed invasion and highest risk sites. Outlining the state of weed invasion of coastal areas, botanist Stuart Cameron stated that there was a rare opportunity to control invasive species threatening coastal vegetation communities across all land tenures. The initial two year project, of which this survey was a component, has been the springboard for a series of successful applications for funding at Federal, State and Local government levels for a number of noxious and environmental weed management, vegetation rehabilitation and restoration projects.

The impetus generated from the diversity and complementarity of these projects has revitalised existing community land care groups, prompted the formation of others and encouraged local residents and visitors to seek information and take action to protect the unique South Coast environment. Over the past six years the incidence of the key target species has been markedly reduced and resources freed up to direct to other weed species and to projects focusing on revegetation and rehabilitation. Volunteer groups have been able to increasingly focus on restoration works rather than being wholly taken up with weed control.

Keywords: Weed management, community awareness, whole of landscape approach.

INTRODUCTION

Despite the consensus in the scientific community that weed invasion is a major cause of the ongoing global loss of biodiversity, the issues of natural resource management and pest plant invasion neither have a high public profile nor are they able to draw upon significant and secure resources. In 2010 'Invasion of escaped garden plants' was submitted for listing as a Key Threatening Process under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, an indication of the seriousness of the threat.

Invasive species are a major cause of the degradation and displacement of native coastal vegetation. A 2007 survey of the Bega Valley Shire Coast showed that 80% of the environmental weed species there had originated in local gardens (Cameron 2008).

The survey found garden escapes concentrated on the periphery of coastal settlements and that they were often very prominent at popular lookouts and picnic spots. While they tend to colonise disturbed habitat and degraded sites, many are very hardy and highly competitive, invading otherwise healthy intact vegetation communities by stealth, compromising the distinctive nature of indigenous vegetation communities, altering soil biology and thus affecting native plants, animals and birds.

Garden escapes are just one weedy issue affecting the coastline with other weedy plants deliberately introduced for a variety of reasons such as stock feed or erosion control. These may be more widespread along the coast, but may also have been and continue to be the target of long-running management programs. An example is bitou bush. Others may have spread to the extent that any control is not feasible.

DISCUSSION

The Far South Coast is at a stage where effective management of weedy species and protection of endangered indigenous plants and high value vegetation communities is achievable but requires a comprehensive long-term cross-tenure approach. Not only must work be done on the ground but, in order to protect the unique nature of the South Coast itself, people must be prepared to take decisions that do not place plant communities at risk and take ownership of their ‘backyard’, actively involving themselves in its protection.

The 'mosaic' of recent projects and initiatives on the Far South Coast (primarily in the Bega Valley Shire):

1. makes efficient use of limited and dispersed resources;
2. raises community awareness and concern;
3. consolidates and focuses the efforts of existing volunteer groups and fosters new ones;
4. trains volunteers and Aboriginal workers in weed identification and control;
5. links weed management with broader natural resource management;
6. brings the new and emerging weed threats into focus;
7. has formed effective and enduring alliances among agencies and the diverse community interests (Catchment Management Authority, Council, National Parks Service, plant nurseries, Landcare, community volunteers, Local Aboriginal Land Councils);
8. has achieved and continues to attain significant results 'on the ground' - in particular having a major impact on local infestations of sea spurge, African boxthorn, pampas grass, polygala and bitou bush.

Coastal weeds management is thus an over-arching single program made up of numerous smaller projects with essentially the same aim – effective environmental management. Identifying and taking action through linked projects at agency and community levels allows a different approach to what is essentially natural resource management at its best – tenure-blind and involving all land managers and the community.

At the start of the project in 2007, community consultations were held in four coastal centres to provide information, identify local weed management and rehabilitation projects, work with participants to identify local issues of concern, update mapping of key infestations and develop locally relevant weed management programs that linked with other coastal communities. One of the key outcomes of all of the projects is to have a better-informed community able and willing to take action to protect their local environment.

While the initial coastal weeds project, focusing on the Bega Valley coastline has undergone a number of iterations it has been the link to and between other vegetation management programs and projects along the South Coast, a number stretching from the Illawarra into East Gippsland with others are more local, that has spelt success for the protection of the unique indigenous vegetation of the Far South Coast.

Many localised rehabilitation and revegetation projects which may target only relatively small areas minimise the likelihood of re-invasion and are linked with the coastal weeds project, now in its third stage and embracing the theme ‘Protecting the Wilderness Coast’.

Landcare groups, many of which long pre-dated the project were initially focused on weed management, but have branched into revegetation projects and development of interpretive walkways.

Why has this model been so successful?

In NRM terms, programs and projects often have a narrow focus and are short-term, limited by funding availability. The highly competitive funding environment makes obtaining financial support, even for the best projects, very challenging and maintaining on-going funding even more-so.

Initial funding for the coastal weeds project provided a springboard for other projects. New project proposals could demonstrate beneficial links to this and other projects in the mosaic, thus showing more value for the investment.

Having a clear long term management strategy founded on robust survey data was also a key asset. Involvement with the community and the tenure-blind approach have ensured broad-based on-going commitment to better understanding and management of the diverse coastal environments.

The success of the projects can be put down to the mix of aims and objectives, the links identified between projects, the vision of the community in the desire to protect their part of the coast and the dedication of all involved.

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A SUCCESS STORY: THE CAPE BROOM PSYLLID, *ARTYINNIS HAKANI*[A]

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SUMMARY Cape broom (Montpellier broom), *Genista monspessulana* (L.) L.A.S.Johnson, is a leguminous shrub of Mediterranean origin. It is widespread in southern Australia infesting over 600 000 ha. Cape broom forms dense thickets in bushland, forestry, grassland, pastures, and recreation areas. It is a newly declared Weed of National Significance (WoNS). The psyllid, *Arytinnis hakani* Loginova was released in September 2010 at Captains Flat on the southern tablelands of New South Wales. Within eight months the psyllid had dispersed widely to a distance of 1.3 km from the nearest release point with shrubs being severely defoliated and producing few flowers and seed pods. Within 19 months, many Cape broom shrubs were dead.

Keywords: Biological control, Montpellier broom, *Genista monspessulana*.

INTRODUCTION

Cape broom (Montpellier broom), *Genista monspessulana* (L.) L.A.S.Johnson is a leguminous shrub native to Mediterranean Europe and north west Africa. It has spread around the world and is a weed in North and South America, Hawaii, Australia and South Africa (Parsons and Cuthbertson 2001). *Genista monspessulana* has formed high-density infestations in all states of southern Australia affecting native vegetation, forestry, grazing, amenity areas and infrastructure (Adams and Simmons 1991, Sheppard and Henry 2012). Infestations can become so thick that virtual monocultures are formed.

In New South Wales, *G. monspessulana* is a declared noxious weed in 52 Local Government Authority (LGA) areas. In 41 of these LGA areas *G. monspessulana* is Class 2 (the plant is a notifiable weed, the plant must be eradicated from the land and the land must be kept free of the plant). In nine LGA areas it is Class 3 (the plant must be fully and continuously suppressed and destroyed) and in two LGA areas *G. monspessulana* is Class 4 (the growth of the plant must be managed in a manner that reduces its numbers, spread and incidence and continuously inhibits its reproduction).

Chemical and mechanical controls are expensive and labour intensive and these options are unable to deal with the long lived and large seed banks that necessitate many years of follow-up control (Parsons and Cuthbertson 2001, Sheppard and Henry 2012). Even when controlled by these methods, the ability of *G. monspessulana* to increase soil nitrogen makes regeneration of native woodland difficult. These problems have led to the conclusion that classical biological control is the only viable long term option (Sheppard and Henry 2012).

Exploration for potential biological control agents was carried out in the Mediterranean region between 1999 and 2005 (Sheppard and Henry 2012). A short list of 10 potential arthropod agents was reduced to two species for rearing and testing in Australia. These were the multivoltine psyllid, *Arytinnis hakani* Loginova, and the univoltine apionid seed weevil, *Lepidapion* nr *argentatum* Gerstacker. Host specificity testing in Australia began in 2003 in quarantine at Adelaide. The risk assessment research focused mainly on the psyllid,

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A. hakani. Generation times of *A. hakani* vary from 30 to 60 days with four generations developing in spring and fewer generations developing in autumn (Ivory *et al.* 2008). Populations over-winter as eggs and over-summer as early instar nymphs.

In 2006, while testing was being carried out on *A. hakani,* and prior to it being officially released, *A. hakani* was found to be present in the Adelaide Hills. *Arytinnis hakani* was widespread over a 120 km range and stored specimens showed that it had been present in the Adelaide Hills since 2004.

All life-stages of *A. hakani* attack young shoots of *G. monspessulana.* Testing showed that the psyllid had the ability to breed on certain species of *Lupinus* which are present but not grown commercially in Australia (Sheppard and Henry 2012). The *Lupinu*s species at risk were not preferred hosts and were all annuals that could not continuously support all generations of *A. hakani* throughout the year. The tests also showed that collateral damage was likely to occur on the *Lupinus* species only when they were in the presence of *G. monspessulana.* The results of the risk assessment and the significant visual damage observed on *G. monspessulana* led to the decision to redistribute *A. hakani* in South Australia and to eastern Australian states.

The aim of this paper is to present the results of a case study that was undertaken following the release of *A. hakani* at a site in New South Wales in 2010.

CASE STUDY

Captains Flat (35°35’18.24”S, 149°26’51”E) is a small town in the southern tablelands of New South Wales, Australia. The town has a long history of mining activity dating back to 1882 that has led to much land disturbance and degradation. In 2010 many localities throughout the district had light to moderate infestations of Cape broom. These were on government and privately owned land.

On 28 September 2010, adult and nymphal stages of *A. hakani* were collected from *G. monspessulana* in the Adelaide Hills using a beating tray. *A. hakani* was sent by overnight Express Post and 200-300 insects were released at sites 1 and 2 on 30 September 2010 (Figure 1).

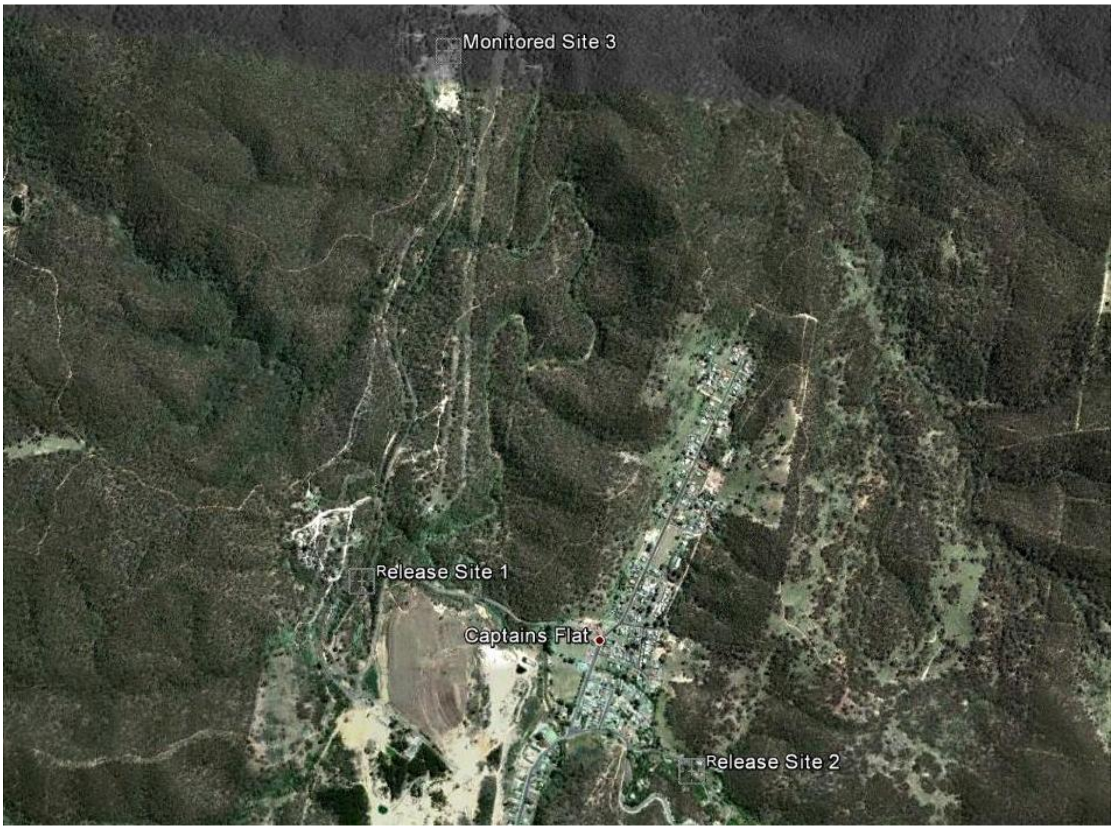

Figure 1. Captains Flat, New South Wales showing release sites 1 and 2, and monitoring site 3 on 11 November 2010. (Image © 2013 Digitalglobe).

On 18 May 2011, more *A. hakani* insects were collected from the Adelaide Hills with the intention of releasing them onto uninfested *G. monspessulana* at Captains Flat on 19 May 2011. However examination of *G. monspessulana* within the Captains Flat district showed that all inspected shrubs were infested with *A. hakani* to a distance of 1.3 km (Figure 1, monitored site 3) from the closest release at release site 1. Many *G. monspessulana* shrubs were severely defoliated by the feeding of *A. hakani* and showed little evidence of flowering or seed production. In some infested areas, every *G. monspessulana* shrub was dead (Figure 2). No other plant species in the vicinity showed signs of damage.

Figure 2. *Genista monspessulana* killed by *Arytinnis hakani*.

DISCUSSION

The observations reported here show that *A. hakani* has been an effective biological control agent of *G. monspessulana* under the conditions prevailing in the Captains Flat district during the case study. Monitoring of *A. hakani* at Captains Flat indicated this psyllid reached high population densities in spring and late autumn, however, during hot summers the populations decreased (P. Sullivan, unpublished data). It is suggested that collection and release of *A. hakani* be made in spring when populations are high and temperatures will be at a level that should enhance establishment.

By December 2012, only a limited number of *G. monspessulana* infestations in New South Wales had been infested with *A. hakani.* As the success of *A. hakani* becomes well known, it is likely that many *G. monspessulana* infestations will be managed with this psyllid.

Excellent control of *G. monspessulana* by *A. hakani* has also occurred in Tasmania where the agent was first released in December 2009. Within two years, large infestations in in southern Tasmania were showing symptoms of severe damage and by the end of 2012 most of the plants in these infestations had died (J. Ireson, personal communication 2013). However, occasional plants in both New South Wales and Tasmania (less that 1% in Tasmania, J. Ireson, personal communication 2013) were found to still be alive in March 2013, which may indicate some level of resistance to attack. It is important that this small minority of surviving plants are monitored closely to determine whether they are able to thrive in the presence of *A. hakani*. Surviving *G. monspessulana* may have a genetic resistant to *A. hakani* and as such should be removed while still in low numbers. Otherwise, resistant *G. monspessulana* plants may increase in numbers and the species eventually return to its former pest status.

In South Australia, biological control of *G. monspessulana* has achieved limited success. Most plants have been partially defoliated and occasional plants have been killed, however, infestations have not yet been controlled. In South Australia, the long hot summers have a noticeable negative impact on populations of *A. hakani* allowing *G. monspessulana* plants to survive (S. Ivory, personal communication 2013). This agrees with the report (Henry *et al* 2008) that *A. hakani* is less effective on exposed north facing slopes and during particularly hot summers.

When conditions are similar to those prevailing during this case study, *A. hakani* is likely to provide successful control of *G. monspessulana.* More case studies are needed to determine the level of control of *G. monspessulana* when conditions differ from those found in this case study.

The classification of *A. hakani* in the New South Wales noxious weed declarations list needs to be revised to Class 4 if *A. hakani* is able to provide widespread control of *G. mospessulana* in New South Wales. This would provide a more realistic and economically viable management strategy for *G. monspessulana.*

ACKNOWLEDGEMENTS

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THE POTENTIAL OF THE SCOTCH BROOM GALL MITE *ACERIA GENISTAE*

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SUMMARY Scotch broom (English broom), *Cytisus scoparius,* is a leguminous shrub of European origin. It is widespread in cooler areas of south eastern Australia infesting over 230,000 ha. Scotch broom forms dense thickets in environmental, forestry and grazing areas. It is a newly declared Weed of National Significance (WoNS) and in NSW is a declared noxious weed in 44 Local Control Authority areas. The gall mite *Aceria genistae* was released in Victoria and South Australia in 2008, in Tasmania in 2009 and in NSW in 2010. Releases in NSW were at the Barrington Tops and at a number of locations on the southern tablelands. In NSW the gall mite has established at most release sites and it is the first Scotch broom biological control agent to establish at the Barrington Tops. The gall mite infests dormant buds in autumn causing them to develop into galls in spring. Galls continue to form and grow on infested shrubs resulting in decreased flowering and in some cases shrub death. Heavily infested shrubs in South Australia died within 5 years of the mite being released.

Keywords: Biological control, Scotch broom, English broom, *Cytisus scoparius*, gall mite, *Aceria genistae.*

CONTROL OF CABOMBA IN LAKE BENALLA AND SURROUNDING ENVIRONS

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SUMMARY Cabomba (*Cabomba caroliniana* Gray) is a Weed of National Significance and was first identified in Lake Benalla in the 1990s. Its dense surface reaching habit poses an entanglement danger for swimmers and is unsightly. Further, this infestation represents a potential propagule source for downstream colonisation of the Broken, Goulburn and Murray Rivers, and associated wetlands (e.g. Barmah Forest Ramsar site).

Summer drawdowns were used to control cabomba in the lake in 1999, 2000 and 2005. However it always returned to problematic levels within a few years. Formal monitoring of effectiveness was not carried out but it was thought recolonisation was probably from populations in channels around Jaycee Island that do not dry.

In 2009 a project was funded through Caring for our Country with the aims of controlling cabomba in the lake and reducing the likelihood of downstream spread. A Project Control Board (PCB) was established, consisting of representatives from Goulburn Broken Catchment Management Authority, Benalla Rural City, Goulburn-Murray Water, Department of Primary Industries and Australian Government Department of Sustainability, Environment, Water, Population and Communities, to guide the control work and make decisions.

Key activities were to map the locations where cabomba was present and develop a control matrix that described control options available for each habitat (lake, disconnected billabong, connected billabong, river channel), along with their feasibility and likely success. A scoring system was applied to rank control options.

Based on the control matrix, winter drawdowns of the lake were enacted in 2009 and 2010, along with pumping of areas where water did not drain and earthworks on the bed of the lake to allow depressions to drain. This resulted in the collapse of cabomba stands in the lake, although a high proportion of the stems and crowns remained viable due to sediments remaining wet or saturated. These drawdowns were followed by floods from September 2010, which would have had at least two effects on the collapsed cabomba. Firstly, the high flows through the lake during the peak flood flow may have both dislodged and buried the collapsed cabomba, depending on their position relative to deposition and scouring zones of the lakebed. Secondly, the floods resulted in increased water level and turbidity for several weeks, both of which would have reduced the light reaching the bed of the lake and therefore reduced the subsequent regrowth of the collapsed cabomba. We cannot separate the effects of the floods and drawdowns, but together they dramatically reduced cabomba abundance (biomass reduced from 441 to 0 g / m^2) and distribution (percent of sampling sites with cabomba present reduced from 86 to 0%) in the lake and Broken River.

Based on this success the PCB changed its aim from suppression of cabomba to eradication. The control matrix was revised and annual management plans were made for all remaining satellite infestations from 2011/12. A summer drawdown was conducted in the lake to kill any cabomba propagules remaining in the sediment, several billabongs with cabomba

were pumped dry, Casey's Weir was lowered, and a stormwater wetland was scraped with a digger.

Intensive monitoring continues at all known sites and three areas remain problematic; an anabranch adjacent to Jaycee Island, Broken Creek downstream of Casey's Weir, and Broken River upstream of Casey's Weir. Activities are planned for 2013 to control cabomba in these areas.

Keys to the success of this program are 1) the co-ordinated effort provided by the PCB, 2) fortuitous timing of natural floods, associated with high turbidity, 3) detailed monitoring of cabomba abundance and viability before and after management activities, 4) re-evaluating aims and activities according to progress, and 5) continued support for the project.

Keywords: *Cabomba caroliniana*, drawdown, Lake Benalla.

BULGANDRAMINE MISSION RESTORATION AND REHABILITATION PROJECT

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SUMMARY The Bulgoandramine Mission Restoration and Rehabilitation Project (the Project) aims to reduce the impact of noxious weeds from spreading onto adjoining properties and to reduce new weed germinations. This Project has enhanced and improved utilised of the site for both social and educational activities whilst allowing the wider community to learn about the local aboriginal history and the cultural significance of the Bulgandramine Mission site (the site) particularly the relatives and passed descendants whom lived on the Mission. The site is owned by the Bogan River Peak Hill Wiradjuri Aboriginal Corporation. This Project is successfully utilising proven control methods and integrating local knowledge to carry out long-term management of Weeds of National Significance (WoNs) on Bulgandramine Mission. The primary weed of concern is African Boxthorn. A range of integrated weed control techniques have been used on the property. Funding though the Protecting Our Places (PoP) Program has enabled the owners plus various stakeholders to achieve realistic outcomes within a specific timeframe. All stakeholders involved are already noticing significant benefits from this ongoing partnership and are confident that the positive changes will be far reaching both locally and regionally.

INTRODUCTION

There is no doubt that Bulgandramine Mission is significant to the Peak Hill Aboriginal community, the site is locally and regionally significant due to the existing native vegetation and importance to the local Aboriginal people. This area is identified as containing a high floral diversity with a good mixture of native grasses, shrubs and trees including river red gums.

The site is located approximately 20km north west of Peak Hill and adjacent to the Bogan River and is considered of great cultural importance to the local Aboriginal people and it is widely used as a meeting place and camping spot.

The primary weed is African Boxthorn with the project aiming to control this and other weeds and to encourage native grasses to regenerate so that the area can be increasingly utilised not only as a meeting place for the Peak Hill Aboriginal community but to protect the environment and the native flora and fauna whilst maintaining biodiversity.

While the development of this project focused on the significance of these two important issues, it has also strengthened the working partnerships with other stakeholders. In particular between the Bogan River Peak Hill Wiradjuri Aboriginal Co-orporation, the Peak Hill Aboriginal Land Care Group, the Peak Hill Aboriginal Working party and Central West Lachlan Landcare who are all working together to achieve the objectives of the project.

Parkes Shire Council encourages and has built a reputation of being successful at fostering existing and developing new relationships with or between various stakeholders.

Parkes Shire Council will continue to be undertaken these activities as it will benefit the community in the long term.

OBJECTIVES

* To reduce the impact on noxious weed and prevent new reinfestations and inhibit the spread of targeted weed species African Boxthorn in order to provide long-term vegetative protection.

* To reduce the spread of invasive species into important nearby high risk waterways (Bogan River) and adjoining properties.

* To employ best management practices, while maintaining ground cover and reduce the competition for the native vegetation (native grasses).

* To assist the community to reduce the habitat for feral animals and fruit fly whilst improving natural habitat for endemic faunal species.

* To carry out a project that everyone can access now and in the future.

* To successfully work together to build long-term relationships that will encourage a sense of ownership and pride amongst the Aboriginal and non-Aboriginal people of Peak Hill.

* To provide employment (Project Officer) to a member of the Peak Hill Aboriginal Community, who works alongside experienced staff from Parkes Shire Council to gain knowledge in the control and management of invasive weeds.

* To improve an amenity for Peak Hill residents and visitors this will benefit the whole community in the long term.

* To map and record the presence of noxious weeds so that the success of the control program can be monitored utilising GPS technology.

* To carry out monitoring over the life of the management program in order to gauge the ongoing success of the methods utilised.

* Provide education to volunteers/ participants/stakeholders through various working bees, workshops, cultural history days, weed management field days, youth empowerment program, Landcare week, planting and seeding revetation days.

* Involve as many stakeholders as possible in the project and sustain a good, local, and working regional partnership.

IMPLEMENTATION

Target audience

- Peak Hill residents
- All Aboriginal and non Aboriginal people
- General public
- Schools
- All farmers/graziers

Who's involved?
- Central West Lachlan Landcare (CWLL)
- Parkes Shire Council staff
- Project Officer (funded by the PoP grant)
- Peak Hill Aboriginal Landcare Group
- Bogan River Peak Hill Wiradjuri Aboriginal Cooperation
- Peak Hill Aboriginal Working Party
- Central West Catchment Management Authority

Stage 1 - July 2012 onwards
- Allocated project budget is $17,436. This included; employment of a Project Officer for 3 hours per week (Shawn Gould from Peak Hill); purchasing herbicides; labor vehicle running costs; various educational activities such as weed and native grass identification and cultural days; hiring a bulldozer; promotion though local papers and radio stations; making signs for entrance and shed; site monitoring and for keeping the stakeholders up to date. Approximately 15,000 litres was used for stage 1 on initial control works

Stage 2 - July 2013 onwards
- A further $17,436 has been allocated to complete the project in 2013-2014. This consists of; re-employing the local Aboriginal person as Project Officer; hiring a bulldozer; continuing to use a wide range of integrated weed techniques; promoting the project though media outlets as well as social media and continuing to have informative information field days/workshops on the site.

ACHIEVEMENTS

The project has enabled existing partnerships to be strengthened and this builds on from previous successful projects carried out over a number of years within Parkes Shire Council. These successful projects have developed strong work ethics by the stakeholders which will result in future joint projects being initiated. By all stakeholders working together stakeholders value each other's contributions are this in turn makes the stakeholders keen to explore implementation of future projects.

An expected outcome of this project is that it has enabled the project to employ a local Aboriginal from Peak Hill (whom has family history with the Bulgandramine Mission). This has been a great opportunity to learn from Shaun the importance of the property in regards to local history in the area and learn from the elders whom still live in the area or surrounding areas. From this various other activities such as cultural history days and NAIDOC activities as well as the involvement of the Youth Empowerment Program has evolved. The children of the Youth Empowerment Program have made a footy field with goal posts utilising tree limbs. This has become a major attraction for all who attend the site on planned and non planned events. Everybody is welcomed on site. The only thing asked of visitors is that they have fun, relax, enjoy the bush and the natural landscapes and help do some weed control using a range of techniques then at the end of the day sit down have a talk, enjoy the company and learn a few things and gain an understanding of the local culture. This leads to increased knowledge on heritage matters and weed control, and brings all the stakeholders together to discuss the possibility of future project opportunities.

The Project objectives are constantly being evaluated using regular contact between all of the organisations involved and by the use of project management tools to carry out ongoing assessment of the objectives. As an ongoing project it requires continual monitoring and checking - the Project is on schedule to achieve positive outcomes.

As of April 2013 Parkes Shire Council has chemically sprayed a total of approximately 20,000 litres on the site to control African Boxthorn. This work has been carried out using Parkes Shire Council's two twin Quik Spray units. A range of integrated weed control techniques has been used like; foliar spraying with selective and non-selective herbicides; cut and paint using loppers around sensitive areas such as the "lagoon" area; mechanical removal using brush cutters and steel blades to lop bushes then application of herbicide to the stumps; a bulldozer has been used to remove any huge clumps around trees which has speed up the Project and reduce overall chemical usage and the use of basal bark application of herbicide..

MONITORING

Monitoring will continue regularly with photos taken before, after and during to show progress. The site has been mapped by Parkes Shire Council's designed PestMapper program. Monitoring points have been set up and will be used as part of the ongoing monitoring process. This involves using the "step by step" method where data at each step is recorded over 100 steps.

On the 17 October 2012 it was determined that 1% of the area was African boxthorn, 31% curly windmill grass, 16% Galvanished burr and 15% Ryegrass. The main trees and shrubs recorded were bimble box, white cypress, ld river gums, white and grey box. The ground at the time as 90% vegetation and 10% bare ground and this is considered to be an excellent condition for restoring native grasses and vegetation on this property.

This project will be successful in the long term if we continue to follow up on the work already completed. This includes continuing to employ Shaun Gould as the Project Officer and working with all the stakeholders.

The project does just concentrate on just one weed species but priority was given to this Weed of National Significance (African boxthorn) through PoP.

This Project also addressed activities in other links Plans and Strategies as well as achieving Project Objectives these include:

1. Reducing the impact of WoNs - in this case African boxthorn.
2. Restoring and revegetate the site, encourage native grasses and sustain the flora and fauna along the Bogan River
3. Addressing Catchment Management Plan Management Targets being:

    - Reduce the area in the Catchment affected by environmental weeds
    - Public land be managed according to integrated management plans that optimises nature conservation
    - Increase knowledge and understanding of the wider community of aboriginal culture and cultural projects
    - Protection of culturally significant aspects of the landscape, both aboriginal and non-aboriginal

4. Identifying high risk pathways, strengthening containment lines and bring infestation under control reducing the risk of new infestations.
5. Addressing Goal 3 (Reduce the impacts of widespread invasive species) and Goal 4 (capacity building and engagement of weed in the professionals) under the NSW Invasive Species Plan 2008-2015.
6. Achieving a local project and engaging in local knowledge.

7. Achieving outcomes with Lachlan and Macquarie Valley Regional Weeds Strategy including:

- o Goal 3.1.1 (Increase working partnerships to benefit the community)
- o Goal 3.1.2 (partner with neighboring Regional Weed Advisory Committee's)
- o Goal 3.2.1 (collate baseline data for current distribution and abundance of weeds
- o Goal 3.2.2 (collect weed data and publish maps)
- o Goal 3.3.4 (Maintain open communication between public and weed managers)
- o Goal 3.5.4 (success stories publicised)
- o Goal 4.2.4 (local field days/ workshops are held).

PROMOTION

The Project has been promoted numerous ways and using a range of outlets regionally. This particular Project has been mentioned numerous times through in the local papers including The Champion Post, The Trundle Star, The Peak Hill Times, Tullamore Times, The LALC Land inTracker Magazine, and been mentioned in the Australian Institute of Aboriginal and Torres Strait Islander Studies. Social media has played a big part with regular updates of the project on the CWLL facebook page. The Central West Catchment Management Authority (CWCMA) and CWLL continually provide regular updates to the community and promote on any events. It has been mentioned numerous times in Parkes Shire Council's reports which are available for the general public.

Two signs have been erected at the front gate site entrance showing the stakeholders involved and who was responsible for the completion of the work. Another sign is located at the shed showing aims of the project.

In October 2012 Parkes Shire Council's weed department along with CWLL and CWCMA attended a cultural day which was aimed at educating the local aboriginal community on weed management. The workshop aimed to produce an on-farm weed identification tool to be used in future reference. Approximately 20 children plus adults attended with the majority age being 12 and 18 years of age. The laminated educational material produced by the children will remain at Bulgandramine and will be on displayed in the shed to increase knowledge of weed management now and in the future..

National Sorry Day was another event that occurred in March 2013 with a bus load of attendees from Parkes and Forbes attending a working bee on the site. Participants took part in weed control on the African Boxthorn using the cut and paint control method. Tree planting activities also took place around the old cemetery using native trees of dodenia, dwarf currajongs, lilly pilly and westringia (Naringa). Forbes Urban Landcare Group representatives also attended to donate 60 River Red Gums in tube stock which were planted on the eastern site of the main shed.

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Parkes Shire Council Noxious Weeds Department
Central West Lachlan Landcare
Bulgandramine Project Officer
Peak Hill Aboriginal Working Group
Peak Hill Aboriginal Landcare
Central West Catchment Management Authority
Bogan River Peak Hill Wiradjuri Aboriginal Co-orporation

ROBOTIC AIRCRAFT AND INTELLIGENT SURVEILLANCE SYSTEM FOR WEED DETECTION[A]

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SUMMARY This paper presents a summary of the autonomous weed detection Research and Development program at the Australian Centre for Field Robotics (ACFR) over the past seven years. The ACFR has used various aerial robots on various detection and mapping projects, targeting weeds including prickly acacia (now *Vachellia nilotica* (L.) P.J.H.Hurter & Mabb.), parkinsonia (*Parkinsonia aculeata* L.), mesquite (*Prosopis pallida* (Willd.) Kunth), wheel cacti (*Opuntia robusta* J.C.Wendl. ex Pfeiff.) and salvina (*Salvinia molesta* D.S.Mitch.) in various parts of Australia. The algorithm research at ACFR leads to various intelligent detection and mapping software systems for accurate terrain mapping, vegetation segmentation and detection of different invasive species.

Keywords: Weed detection, pest detection, robotic aircraft, intelligent systems.

INTRODUCTION

Over the last seven years the Australian Centre for Field Robotics (ACFR) at the University of Sydney has been developing robotic air vehicles and intelligent software systems for environment monitoring with particular emphasis on weed detection and eradication. In particular the work has focussed on developing air systems that can not only fly fixed flight paths but also use information gained from on-board sensing systems to determine optimal flight routes in real-time to maximise map and weed classification quality. These sensing systems comprise visual and near infrared, and include machine learning algorithms that can build accurate terrain maps, vegetation segmentation and detect different weed species once trained.

The work has been funded by Land and Water Australia, the Australian Weeds Council, Meat and Livestock Australia as well as funding from the Australian Research Council. Both aquatic and terrestrial weeds were part of these studies.

This paper will discuss these projects including the development and testing of the surveillance system for environment monitoring. The paper will also discuss the current system that is being trialled for operational use in weed monitoring, and future work in the area. The aerial weed detection projects are described below, followed by details of the aerial robots and the intelligent software detection algorithms. The detection results are then discussed.

PROJECT SUMMARIES

The Australian Centre for Field Robotics has applied the weed/pest detection research on four different applications. Each involves different species in various environmental settings.

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The woody weed detection project focused on the detection and mapping of prickly acacia (now *Vachellia nilotica* (L.) P.J.H.Hurter & Mabb.), parkinsonia (*Parkinsonia aculeata* L.) and mesquite (*Prosopis pallida* (Willd.) Kunth) in central Queensland (Bryson *et al.* 2010, Hung *et al.* 2012a, b). These weeds cause significant damage to the environment by out-competing native species and reduce rangeland grazing production due to difficulties in land access and cattle mustering.

The cacti detection project focused on the wheel cacti (*Opuntia robusta* J.C.Wendl. ex Pfeiff.) in large area of rangelands in South Australia (Bryson and Sukkarieh 2011). The wheel cacti are drought resistant and have recently been listed as new Weeds of National Significance.

The aquatic weed detection project focused on salvinia (*Salvinia molesta* D.S.Mitch.) (Sukkarieh 2008). Salvinia has infested large areas of waterways in New South Wales and Queensland: infestations have also been reported in other parts of Australia. Salvinia affects the native species, disrupts waterways and interferes the river control structures.

Examples of the Australian Centre for Field Robotics Unmanned Aerial Vehicle weed detection projects are summarised (Figure 1).

Woody weeds	**Cacti**	**Aquatic weeds**

Figure 1. Weed detection projects have been conducted for various weed groups.

METHODOLOGY

The aerial data were collected mostly using the robotic platforms used in the Australian Centre for Field Robotics. For eachvproject, a region of interest with suspected weed infestations is defined and the robotic platforms then follow a pre-defined flight trajectory to collect aerial images of the entire region of interest.

The aerial images consist of standard Red, Green and Blue (RGB) images: for the weedy wood project hyperspectral data were also collected via manned aircraft. The aim of the image analysis algorithms is to detect and map the target distribution using the collected aerial images. The robotic platforms and the detection algorithms are described in the following sections.

Robotic platforms

Three ACFR aerial robotics platforms have been used in the weed detection projects (Figure 2): a Hovering Unmanned Aerial Vehicle (HUAV); a scaled-down autonomous J3 Cub; and a hexacopter. All platforms are equipped with cameras to obtain aerial images, global positioning systems (GPS) and Inertial Measurement Units (INU) for navigation and on-board computer for control. In addition the HUAV is equipped with a spraying system for the optional control and eradication flights.

		
HUAV	**J3 Cub**	**Hexacopter**

Figure 2. Australian Centre for Field Robotics aerial robotic platforms used in weed detections.

Detection algorithms

The intelligent software detection algorithms developed for these projects followed the same overall pipeline with interchangeable sub-components. The main stages of the piplelines are image-pre-processing, feature extraction/learning and finally detection, classification and segmentation (Figure 3).

Figure 3. Detection algorithm overview.

The aim of image pre-processing is to format the data to simplify the analysis in later stages. Techniques such as 'noise' removal, data normalisation and whitening, and the use of super-pixels to group similar neighbouring pixels have been used.

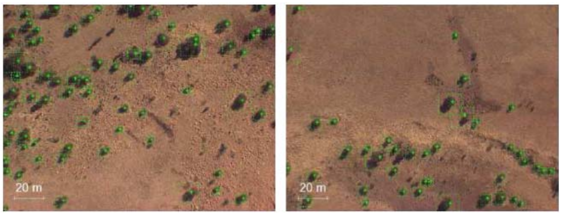
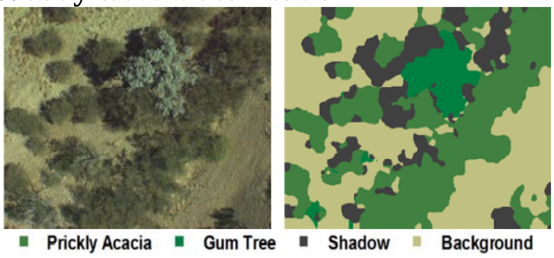
The following stage is to obtain features either through selection or learning. Features are compact representations of the data. A classification algorithm typically performs better using the statistics extracted using the features instead of using the original data. In these projects standard vision features such as colour (RGB, hyper-spectral and multi-spectral channels), texture (defined by banks of Gabor filters, Laplacian pyramids) and shape (a tree-crown template) have been used. In addition we have also explored the state-of-the-art feature learning techniques to obtain features that outperformed the standard feature set.

The last stage is to perform classifications based on the feature responses. In the training step the classifiers take the feature response with the training label to learn a classification model: this is followed by an evaluation step before the algorithms can be applied to the rest of the dataset. In these projects, we have applied various classifiers including a logistic-regression classifier, support vector machines (SVM), LogiBoost and a Gaussian process classifier.

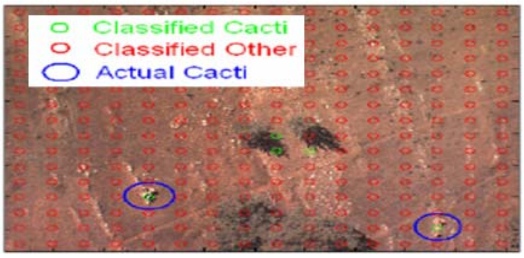
RESULTS AND DISCUSSION

The classification and segmentation results of the projects are summarised (Table 1). For the weedy weed detection project, we applied a tree crown detection algorithm on the high altitude flight to obtain the vegetation count and overall vegetation distribution, achieving a detection accuracy of 80%. A class segmentation algorithm is then applied on the images obtained during the low altitude flight to classify individual species, achieving an overall class segmentation accuracy of 95%.

Table 1. Summary of classification and segmentation results.

<table>
<tr>
<td>Tree crown detection

Achieved an overall detection accuracy of 80% (Hung et al. 2012a)</td>
<td>Woody weed classification


Achieved an overall class segmentation accuracy of 95% (Hung 2013, p. 126)</td>
</tr>
<tr>
<td>Aquatic weed detection

(Sukkarieh 2008)</td>
<td>Cacti detection


Achieved an overall accuracy of 84%. (Bryson and Sukkarieh 2011)</td>
</tr>
</table>

A binary segmentation algorithm has been applied on the aquatic weed detection program to obtain the weed coverage map. A patch classification algorithm has been applied in the cacti detection program to generate the cacti distribution map with an overall detection accuracy of 84%.

In these projects we have demonstrated the ability of ACFR autonomous remote sensing data collection using robotics platforms. On the data analysis side, we have showed that with a carefully structured algorithm pipeline coupled with machine learning algorithms, that we were able to apply similar analysis pipelines to detect, segment and classify different species of weeds.

CONCLUSIONS

In the past seven years ACFR has developed a system for the environmental surveying missions from the aerial robots used to collect the aerial imagery autonomously, to the intelligent software pipeline to detect and map the target weed from the aerial images. This system has been applied to three different projects in various parts of Australia and the research has shown state-of-the-art detection and classification results that could be beneficial to the local communities.

ACKNOWLEDGEMENTS

The work has been funded by Land and Water Australia, the Australian Weeds Council, Meat and Livestock Australia as well as funding from the Australian Research Council and Biosecurity Queensland.

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DISASTER MAPPING, DATA MANAGEMENT AND COORDINATION POST BLACK SATURDAY FIRES CASE STUDY

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SUMMARY The last few years have highlighted the unexpected devastation that climate /weather based natural disasters can impact our communities. Many regional organisations have been struggling with collecting and disseminating quality information post disaster to support decisions about recovery efforts, rapid impact assessments and response priorities post flood and bushfire. The Black Saturday Fire response and recovery efforts in 2009 at Nillumbik Shire Council, clearly demonstrated the advantage that organisations have when their mobile GIS/ GPS field solutions for data capture are robust and can be ramped up to coordinate and inform everyone associated with recovery efforts post disaster. The importance of capturing accurate and reliable information about destroyed and damaged properties, displaced and deceased residents, and injured or dead animals is a huge undertaking. This presentation uses data from the Black Saturday recovery at Nillumbik Shire Council as a case study to demonstrate the advantages of rapidly ramping up Mobile Workforce strategies for field activities taking advantage of mixed mobile computing devices, GPS, digital images and streamline data flow across corporate systems.

Keywords: Post Disaster Data Capture, mobile GIS, disaster recovery, Black Saturday Bushfire, WeedMap Pro, Crest software, mobile computing, recovery coordination, rapid impact assessments, emergency management, mobile mapping, mobile workforce.

INTRODUCTION

Having worked with all tiers of government clients in emergency services and municipal capacities over the last 20 years in Australia and in USA, we have continuously evolved solutions that deliver tangible mobile mapping and dynamic geospatial intelligence gathering from the field and distribution to other users to connect the disconnected.

This presentation demonstrates how clients have identified risks, improved spatial data, extended the reach of their corporate systems and learned some important lessons to achieve interoperability. We will discuss and present what we have learned in the pre, during and post disaster projects which will include:

- GIS Data Capture versus Workforce Mobility (Why traditional GIS doesn’t work)
- Data management /data currency strategies
- What Mobile field teams want and need to conduct property inspections pre, during and post incident
- Examples of integration to connect field & office
- Digital forms with Built in logic, Business Rules & QA
- Simplicity & syndication for field users to share data easily
- Inspired to use of new technologies

Post Black Saturday Bushfire Field response and recovery at Nillumbik Shire Council demonstrated how to achieve increased efficiencies in operations, to reduce risk and to save time, dollars and lives!

BLACK SATURDAY FIRES – NILLUMBIK SHIRE COUNCIL (NSC) RESPONSE AND RECOVERY OVERVIEW

Event and extent of damage summary:

- Fire storm February 7th 2009 starting in Kilmore, Victoria
    - 45 degree day
    - High winds
    - Fire burns through northern parts of State
- Impact on Nillumbik Shire
    - 127 houses destroyed & 8 damaged
    - 9800 ha 23% area of Shire
    - Loss of 41 life, 25% of fatalities occurred in NSC
    - Destroyed property, wildlife, livestock
    - Destroyed signage, infrastructure
    - Displaced residents
    - Entire communities affected
    - Environmental devastation
    - Domestic & livestock animal survivors

Nillumbik Shire Council staff initially tried the traditional paper based system. It was not satisfactory. There are several issues to consider in a post disaster scenario such as:

- Dangers & challenges when mobilizing Council teams to the field Post Disaster
- Fire damaged and destroyed sites (Figures 1 and 2) – many risks (chimneys, gas cylinders, forensic coordination, working with disaster identification teams from police)
- No signage /distorted landmarks – people became easily lost
- Need to know where the Field Inspectors were
- Personal safety (Figures 1 and 2)
- Accuracy of data
- Police restrictions
- Need the data to be auditable (Royal Commission or investigations?)
- Needed to respond and prioritise resources as quickly as possible
- Distraught and injured domestic, native and livestock animals

NSC quickly repurposed Iconyx's Crest applications for new groups of users with no GIS or mobile computing experience such as: Building Inspectors, Health Inspectors, Local Laws and Animal Control.

Figure 1. Rapid impact assessment on site**.**

METHODS

This presentation will show why GIS mapping and mobile computing alone is not sufficient to rapidly respond and deploy services to help the community to recover from natural disasters. The mobile work force needs to work near real time with quality data that is rapidly shared through robust data management processes. Integration with other corporate systems helps to bring everyone into alignment with respect to disaster coordination, reporting and prioritization of efforts.

Nillumbik Shire Council used mobile computing equipment and applications as supplied by the Iconyx division of RapidMap. The equipment, processes, application architecture and workflows are the same as commercially available and built into WeedMap Pro as used widely across NSW Weeds authorities.

Figure 2. Dangerous property site – identifying risks.

RESULTS AND DISCUSSIONS

When disaster hits the important things organisations need to know. Successful response and recovery requires Spatial Data mobilisation across multiple, concurrent users, with multiple devices and a data management architecture.

Mobile Devices with integrated camera & GPS are essential for success in the field.
Field data collected and reports generated from Nillumbik Shire Council became important evidence for the Victorian Royal Commission into the Black Saturday Fires. Several recommendations have been handed down from this enquiry.

ROYAL COMMISSION RECOMMENDATIONS – Next Steps

Following recommendations from the Royal Commission, Nillumbik Shire Council has now engaged RapidMap Services using internally built software called **Fire Assess,** to conduct road side assessments in terms of fire risk on the native and agricultural land verge.
For more information on this go to: www.rapidmap.com/fireassess

2009 also saw the Release of the WeedMap Pro solution for NSW Weeds Authorities with architecture based on the experiences and application of effective field workforce mobilisation from the Post Black Saturday Fires response and recovery coordination.

ACKNOWLEDGEMENTS

Thanks and acknowledgements go to Nillumbik Shire Council, Brisbane City Council, Aerometrix, Emergency Services Telecommunications Authority (000) in Victoria, NSW Rural Fire Services, RapidMap and Iconyx.

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APPENDIX:

Sharing knowledge and shaping the future of Local Government post disaster response

Nillumbik Shire Council were recipients of LG Pro excllence awards in 2009 and the 5th Annual Victorian Spatial Excellence Award for their outstanding efforts.

Mayor Ken King and Iconyx Director Lynnette Terrett accepting award.

SPATIAL INVASION PATTERNS OF HAWKWEED

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SUMMARY *Hieracium* species have invaded over 6 million hectares of New Zealand grassland shrubland and forest ecosystems since introduction with European colonisation in the 1850's. Species can spread by two means, either by stolons and seed (subgenus *Pilosella*) or only by seed (subgenus *Hieracium*). This study examines spatial invasion patterns of three sympatric species in subgenus *Pilosella* (*H. caespitosum*, *H. pilosella* and *H. praealtum*) and one in subgenus *Hieracium* (*H. lepidulum*) in montane snow tussock (*Chionochloa rigida*) grassland. *Hieracium* species were recorded in contiguous 33 cm^2 quadrats in 200 – 440 m^2 of grassland at three sites between 930 – 1225 m altitude. Exclosures established in 1960 and 1964 allowed assessment of herbivory on invasion rates. Sites were assessed between 2006 and 2013. *Hieracium* distributions were significantly non-random for species in both subgenera, implying both clonal spread and short-range order seed dispersal are important invasion mechanisms.

HAWKWEED SURVEILLANCE IN THE ALPS

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SUMMARY Orange Hawkweed was brought into Australia by immigrants working on the Snowy Mountain Hydro Scheme. It did not flourish due to the harsh environment and so was not identified as a risk. As a result of the 2002 Alpine Bushfires it "escaped". Currently in the Alpine regions, if it gets into the warmer low lands it has the potential to "moonscape" vast areas of the environment. The weeds can only be identified in about a 2-week window (between flowering and setting seed), so identification, marking and GPS location recording for spraying contractors and year on year reinspection is critical to be done correctly. The correct field method and importantly the correct use of GPS is of the upmost importance in the fight against Orange Hawkweed. This short presentation will explain the procedures developed between a weed expert and the expert in GPS and mapping (4D Global).

YAMAHA RMAX UNMANNED AGRICULTURAL HELICOPTER
An innovation in noxious weed control

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SUMMARY Australia has an innovation in noxious weed management, called the Yamaha RMax Unmanned Agricultural Helicopter. Ideal for controlling infestations in water situations or steep, undulating terrain where occupational health and safety (OHS) issues exist, the RMax Unmanned Agricultural Helicopter provides exponential productivity gains and operator safety.

First developed in Japan in 1983, there are currently over 2,500 units in operation across Japan, South Korea and Australia. It is nearly four metres long and powered by a 246cc two stroke engine, with a number of fail-safes including a self levelling swash plate to avoid rollovers and the ability to land itself if it loses signal from the transmitter. Operation of RMax Unmanned Agricultural Helicopters is heavily regulated in Australia.

Offered via franchise through Yamaha Sky Division Australia, each pilot must hold a Civil Aviation Safety Authority (CASA) Unmanned Aerial Vehicle controller license. They are also subject to International Traffic in Arms Regulations (ITAR), prohibiting possession or use by unauthorised people. This means the helicopters are not available for recreational use and can’t be sold outright.

Keywords: Yamaha RMax Unmanned Agricultural Helicopter Noxious Weeds Productivity Safety

INTRODUCTION

Australia has an innovation in noxious weed management, called the Yamaha RMax Unmanned Agricultural Helicopter. Ideal for controlling infestations in water situations or steep, undulating terrain where occupational health and safety (OHS) issues exist, the RMax helicopter provides exponential productivity gains and operator safety.

In Japan, Yamaha developed its first unmanned helicopter in 1983 – a counter revolving, dual rotor system known as “RCASS”. It was created to dust rice paddies due to the increasing number of buildings and infrastructure built in farming areas, which presented an increasing number of hazards to full size helicopters performing the same task.

This evolved into a scale helicopter model in 1990, called the “Yamaha Aero Robot R-50”. This machine could dust rice paddies in 1/15th the time it took the human workforce to complete the same task manually.

The RMax platform was launched in October 1997 and although improvements have been made over the years, its performance and reliability ensures it remains the design of choice today, with 2,400 units operating in Japan.

SPECIFICATIONS

Overall length of the craft is 3.63 metres and it is powered by a 246cc two stroke twin cylinder engine, producing 85dB of noise. Flight duration is 45 to 60 minutes, consuming six litres of two-stroke fuel in that time depending upon payload and flight manoeuvres.

Payload capacity is 28kg which, after allowing for the spray pump and boom, provides a 16 litre chemical capacity across its two eight litre quick change cassettes. The spray bar is 1.5 metres wide and the rotor blades have been engineered with static inboard flaps to provide dynamic rotary downwash to minimise spray drift.

SAFETY

From a safety viewpoint, the best and most suitable characteristic of an unmanned helicopter is that it carries no pilot. Therefore, no crew members are injured - even if a catastrophic accident were to occur. Also, the RMax is never flown above people or populous areas. Travelling at only 20km/h, at an altitude of three metres above the canopy, there is a very low probability of property being damaged.

There are also a number of operator aids and fail safes built into the craft. These include a self levelling swash plate to avoid rollovers during flight, an over speed warning light to prevent induced drift, and the ability for the craft to land itself if it loses signal from the transmitter. Finally, the chemical capacity of the craft is 16 litres. Designed for ultra low volume chemicals, the small payload ensures that any secondary effects of canister leakage resulting from accidental impact would be minimised and contained to a very small area.

METHODOLOGY

The craft is flown by a controller standing upwind, behind the line of flight at all times. Flight operations are strictly line-of-sight in daytime conditions only. No night flying is permitted. For larger areas without undulation, a forward-and-backward flight pattern is flown, as the controller walks sideways with a constant view of the rear of the craft.

In spot spraying situations, the craft is flown to the target area and hovers at a point triangulated by the controller and a second person also standing upwind, though offset at 90 degrees to the craft's flight path. Once a stable hover is achieved, the spray unit can be switched on to treat a noxious weed.

Spray volume can vary with the crafts' forward speed. Controlled by onboard computers with the aid of Global Positioning System (GPS) logging, the pump will operate more vigorously at higher craft speeds. This ensures that application rates are uniform in flight.

With a pump capable of three bar of maximum pressure matched to nozzles producing very coarse droplets, the average coverage rate is 30 litres per hectare.

REGULATION

Operation of the RMAX unmanned agricultural helicopters is heavily regulated in Australia. Starting with the importation of the craft, they are a restricted item on the International Traffic in Arms Regulations (ITAR), as administered by the United States of America. This requires all personnel and businesses coming into operational contact with a craft to satisfy detailed security background and purpose-of-use checks.

Yamaha Motor Australia must also be able to prove where the helicopters are at any time, should a government authority ask. Operated under a franchise system through Yamaha Sky Division Australia, each franchisee must have a Civil Aviation Safety Authority (CASA) issued Unmanned Operators' Certificate to conduct commercial work.

Each individual operator must also hold a CASA unmanned aerial vehicle controller license, which is very close to a full size helicopter qualification. In each state, various

Department of Primary Industries (DPI) bodies regulate the dropping of herbicides from the RMax craft also.

These restrictions mean the helicopters are not available for recreational use and can't be sold outright, though you'd probably need a very good bank manager if they could be, with each one costing A$125,000.

OPERATION

The Yamaha RMax Unmanned Agricultural Helicopters will be operated under a franchise agreement with Yamaha Motor Australia. Primarily zoned to the east coast of Australia, each franchisee will undergo background checks, training, testing and licensing across various authorities.

Once this process is complete, each franchisee will then conduct contract spraying for paying customers, using a fully leased machine. Yamaha RMax Unmanned Agricultural Helicopters are serviced every 100 hours, just like a full size aircraft. They are re-lifed at 500 hours, being completely stripped down and rebuilt.

After 1,000 hours, the airframe and related components have met their end-of-life timespan. Vibrational and torsional stresses can cause micro fractures in components which would then need to be crack tested for re-certification. Due to the economic impost this creates to a tool of the trade, Yamaha Motor Australia simply crush the helicopter and provide evidence to the Australian government to satisfy ITAR requirements.

A new unit is then sent out to the franchisee, ensuring a high level of reliability and serviceability within the fleet.

Figure 1. Accessing aquatic weeds or dangerous terrain is a thing of the past with Yamaha's RMAX unmanned agricultural helicopter

CONCLUSION

The unique Australian terrain, with boggy areas and steep, undulating hills is the perfect place to showcase the productivity and safety gains available with the RMax (Figure 1). Yamaha Motor Australia has reviewed a number of sites along the east coast of Australia, from Queensland to Tasmania.

Varying in slope, size and treatable material, each location presents its' own challenges in treating noxious weeds. I'm happy to say that we have not yet encountered a location that could not be treated using this craft; whilst realising safety and productivity gains.

Yamaha Motor Australia is currently the only commercial entity offering remote craft of this size for this type of commercial work in Australia. Through ongoing development and work with our commercial partners, we aim to have many more uses for the Yamaha RMax Unmanned Agricultural Helicopter in Australia over the coming years.

HAWKWEED IN NZ AND THE CURRENT SEASON'S RESEARCH RESULTS

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AgScience Ltd. New Zealand

SUMMARY *Hieracium* was first recorded in New Zealand in 1864. The probable founder incursion, of *H. pilosella* in Canterbury, was localised and slow to spread as it was not mentioned in subsequent accounts of naturalised flora until 1920. Orange hawkweed, *H. aurentiacuum*, was reported in 1911 in North Canterbury. By 1920 *H. pilosella* was well established in localised mid- Canterbury pastures and *H. praealtum* was profuse in the upper pastures of the mid- Canterbury plains and adjacent stream gorges. Small patches of *H. aurentiacuum* were also found but were eliminated by cultivation. In the early 1960's a comprehensive survey of Canterbury tussock grasslands showed that *H. pilosella* and *H. praealtum* were widespread, well established, and occasionally very dense. A further species, *H. lepidulum*, occurred sporadically with its greatest frequency in montane short tussock grassland. Nine *Hieracium* species and one hybrid are now present in North and South Island hill and high-country grasslands, shrublands and forests. They occurred in over 6 million hectares in 1992 and were estimated to be common in 4.8 million hectares, conspicuous in 1 million ha, and dominant in half a million ha. Hawkweeds are capable of ecosystem transformation, and have completely eliminated indigenous short tussock grasslands over extensive areas. Environmental modelling indicates that similar invasion dynamics will occur in Australian *Hieracium* incursions unless they are effectively controlled.

BORDER SECURITY: SPOTLIGHT ON WEEDS[A]

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SUMMARY Australia formally adopted the Pheloung Weed Risk Assessment (WRA) system to screen new plant introductions in 1997, following the 1996 'Nairn' Review of Quarantine (Nairn 1996). Since the adoption of the WRA system, roughly 3000 plants have been assessed with 47% accepted for importation into Australia, 24% prohibited due to their high weed risk and 29% requiring further evaluation. Despite the large number of WRAs resulting in an 'accept' result, attempts are still being made to illegally import seeds and live plant material. Millions of people, mail parcels, baggage, ships, animals, plants and cargo containers entering Australia are inspected for prohibited articles by Department of Agriculture, Fisheries and Forestry (DAFF) staff every year. In 2012 alone, roughly 26 000 consignments of seeds and 7 100 items of live plant material were seized. The main route of entry was through international airports in passenger baggage. The most commonly seized seeds and live plants were garden ornamentals. Indonesia was the most common country of origin for seized seeds whilst India was the most common country of origin for seized live plant material. As quarantine risk material is not evenly distributed with arriving passengers and goods, DAFF is implementing reforms to Australia's biosecurity system to better manage the risks of pests entering, establishing and spreading in Australia by targeting areas of highest risk.

Keywords: Weed risk assessment, quarantine.

INTRODUCTION

In the years following European settlement, more than 26 000 plant species have been introduced into Australia for horticultural, ornamental and/or agricultural purposes (Randall 2007). Of these, more than 2 700 have become naturalised in Australia, with the number of naturalised plants increasing by 10–30 species per year (Groves 1997). Within the naturalised flora, 429 species are declared noxious weeds under State/Territory legislation or are under some form of active control in Australia (Groves *et al.* 2003).

In 2004, the economic cost of weeds to Australian agriculture was estimated to be close to $4 billion per year (Sinden *et al.* 2004). The environmental cost is also high, with weeds second only to habitat loss as a cause of biodiversity loss (DSEWPaC 2012). Consequently, the most cost effective and technically feasible means of managing new weed incursions in Australia is preventing their initial introduction.

QUARANTINE IN AUSTRALIA

The weed risk assessment process

For well over a century, introductions of new plants into Australia went unchecked until the establishment of the Australian Government *Quarantine Act 1908.* Under the Act, a quarantine officer could quarantine any plant if they felt it posed an unacceptably high risk.

[A] This paper has been published in Plant Protection Quarterly, Volume 28 No 3.

However, the Act was primarily concerned with potential disease transmission or insect infestations and plants were not systematically assessed for weed potential until 1991. Quarantine in Australia was reviewed in 1996 (Nairn *et al.* 1996) resulting in Australia's formal adoption, in 1997, of a Weed Risk Assessment (WRA) process to screen new plant introductions. The WRA process is a science-based, quarantine risk analysis tool used for determining the weed potential of new plants proposed for importation into Australia as seeds, nursery stock or tissue culture. It is a three-tiered process (Riddle *et al.* 2008) that utilises the Pheloung (1995) system as its second tier. The objective of the process is to pre-screen material so that non-invasive plant species can be imported, while preventing potentially invasive species from entering Australia. The assessment is conducted irrespective of the country of origin or the intended end-use. The system is transparent and meets Australia's international obligations, including those of the World Trade Organisation Agreement on the Application of Sanitary and Phytosanitary Measures and the International Plant Protection Convention.

Since the adoption of the WRA system, over 6 000 plants proposed for importation have been processed by the Australian Government Department of Agriculture, Fisheries and Forestry (DAFF) with roughly 3 000 requiring formal assessment using the Pheloung (1995) system. Forty-seven percent of species assessed using the Pheloung (1995) system have been permitted entry into Australia due to their low risk of becoming weeds, 24% have been prohibited due to their high weed risk and 29% require further evaluation. Species may require further evaluation when there is insufficient information to conduct an assessment or when the plant has a mix of both weedy and non-weedy traits. Species requiring further evaluation are prohibited entry into Australia until additional information becomes available to allow reassessment.

Requests to import plants are received from hobbyists, gardening societies, wholesale and retail nurseries, horticultural companies, agriculture suppliers, botanical gardens, research institutes, state government departments, genetic resource centres and private enterprises. However, the vast majority of applications come from hobbyists who apply for one or two ornamental plant species only.

Table 1. Seizures at Australian international mail centres, airports and seaports in 2012.

Entry Method	**Total seizures**	**Undeclared seizures**	**Seed and Live plant seizures**
Airport	280 000	45 000	25 000
Seaport	6 000	500	600
Mail centre	46 000	46 000*	7 700

*All mail seizures are considered 'undeclared' regardless of the declaration made on the article.

Implementation of quarantine policy

Despite the large number of WRAs resulting in the species being permitted entry, attempts are still being made to illegally import seed and live plant material into Australia. Every year DAFF screens, inspects and clears millions of people, baggage, mail items, ships and cargo containers entering Australia for prohibited articles. In 2011–2012, Australia received around 1.7 million sea cargo consignments, 17 million air cargo consignments, 16 million international passengers and crew, and 177 million mail items. Of these, DAFF intervened with 310 000 sea cargo consignments, 820 000 air cargo consignments, 6.9 million passengers, 52 million mail articles and conducted 21 000 vessel inspections. Approximately 330 000 items were seized at international mail centres, and from international airports and seaports around the country. Close to 28% of these items were undeclared, and 10% of all seizures consisted of seeds and/or live plant material (Table 1). The main method of entry for seed and live plant material was through international airports in passenger baggage with roughly 20 000 seed items and 5 000 items of live plant material seized.

Garden ornamentals accounted for the majority of illegal introductions of seeds and live plants. Alarmingly, escaped garden ornamentals are also the primary source of new naturalised plants in Australia and are by far the greatest source of agricultural and environmental weeds (Groves *et al.* 2005). In 2012, Indonesia was the most common country of origin for seized seeds whilst India was the most common country of origin for prohibited live plant material.

In the years following the implementation of the WRA process, there have been high numbers of prohibited species being seized at the international border. For example, in 2010 live *Hygrophila costata* Nees (Glush weed) plants were seized at the international border. Glush weed is an invasive and noxious aquatic weed in south-eastern Queensland and has been ranked among the top 20 most invasive plant species in the region. The species' range extends from Queensland along the coast of New South Wales to the greater Sydney region. Glush Weed occupies shallow water habitats, particularly along the perimeter of freshwater lakes and slow-moving streams. Aquatic weeds are of particular concern due to their ability to choke waterways, starving the system of light, oxygen and nutrients. Aquatic weeds also obstruct the access of livestock to water and alter the flow of water in irrigation channels, as well as compete with beneficial native plant species, causing a reduction in biodiversity and loss of habitat for animals that use the waterway. The seizure of these plants at the international border prevents the potential spread of Glush weed into new areas in Australia.

Aside from weed risk, illegally imported plants and seeds present a variety of biosecurity concerns including infestations of exotic insects, contamination with soil which may also carry pathogenic agents and plant diseases, or infection from fungi, bacteria, viruses or nematodes.

Biosecurity reform

While geographical isolation has played a key role in maintaining Australia's freedom from some of the world's most severe pests[A], biosecurity risks are growing due to increasing passenger and trade volumes including: greater numbers of imports from higher risk sources; population growth and spread into new areas, bringing people and goods closer to agricultural production and natural ecosystems; increasingly intensive agriculture; increased globalisation; and climate change. Following the 'Beale' review of quarantine (Beale *et al.* 2008), DAFF is implementing reforms to Australia's biosecurity system to better manage the risks of pests entering, establishing and spreading in Australia and potentially causing harm to people, the environment and the economy.

Biosecurity risk is not evenly distributed in arriving passengers and goods. Consequently, a key component of the biosecurity reforms is a change from mandatory intervention at the border to a 'risk-based' approach. This approach enables DAFF to direct more time and resources towards areas of higher risk to Australia's biosecurity by freeing up resources from areas with comparatively low degrees of risk. This approach also recognises and encourages good biosecurity compliance behaviour. Other key reform themes include:

[A] Any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products. Note: In the International Plant Protection Convention (IPPC), plant pest is sometimes used for the term pest (FAO 2012).

managing biosecurity risk across the continuum - offshore, at the border and onshore; strengthening partnerships with stakeholders; intelligence-led and evidence-based decision making; and being supported by modern legislation, technology and business systems.

For example, processed cocoa imports have historically required 100% inspection. Following a reassessment of the risk and a review of the compliance history, it was found that no pests of quarantine concern had been detected on inspected processed cocoa. Consequently, the inspection rate was cut to 5%. In addition to the obvious cost benefits associated with reduced inspection rates, this change has enabled DAFF to direct greater resources towards analytical systems and intelligence to target illegally imported goods, such as seeds and live plants. Moreover, additional import conditions have been implemented for higher risk commodities, such as tomato seeds, which now require testing for emerging seed-borne pathogens.

CONCLUSION

Since 1908, quarantine has played a critical role in maintaining Australia's freedom from serious pests present in other parts of the world. The WRA process in particular has proven to be highly effective at preventing the introduction of potential weeds into Australia. Current reforms to Australia's biosecurity system will further improve quarantine procedures and provide greater protection for our agricultural industries and environment.

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THE DETECTOR DOG CONTRIBUTION TO INVASIVE WEED LOCATION MANAGEMENT & ERADICATION – BITOU BUSH (*CHRYSANTHEMOIDES MONILIFERA* SSP. *ROTUNDATA*)

Peter Crumblin and Charmaine Crumblin
Australian Working Dog Solutions

Can detector dogs assist in the location, management, control and eradication of invasive weeds?

The answer to this question is undoubtedly yes when consideration is given to research such as that offered by Goodwin, Engel, and Weaver in their paper published in the Weed Science Society of America (WSSA) Invasive Plant Science and Management Research document 2010.

The question that I pose however, relates not to the ability to detect but more to the efficiency and effectiveness of utilising these unique capabilities. Of course the detector dog must be appropriately trained and certified for the purpose of detection of target invasive weeds prior to consideration of adding value to your team, however consideration should be given to assessing what obstacles exist which may impact on the successful utilisation of the services provided by such a dog team.

To answer this question we look at the components of detection:

1. Odour (Scent) recognition, discrimination and response.
2. Operational commitment and capability by both dog and handler to perform the task.
3. Dog and handler selection - key elements to success.

This paper addresses the key issues that significantly impact on detector dog team performance and specifically in the operational field conducive to invasive weed proliferation.

To understand the role, training and operational usage of detector dogs and how each "task" has its own specific set of variables, that MUST be taken into account by any organisation wishing to maximise the usefulness of the detection dog capability. This paper and presentation highlights the traditional roles that detector dogs are engaged in e.g. Explosives, Drug and Quarantine Detection and the more relevant field based applications of Cadaver detection and Breech Strike in sheep and how these skills and concepts of operation can be modified to assist in the fight against Invasive Weeds.

In addition to the examination of the aforementioned issues, a trial will be conducted during July and August 2013 (prior to the conference) to ascertain the detector dog's ability to recognise, locate and respond to Bitou bush, samples of which are currently being sourced by Shoalhaven Council Officers. The outcome of this research will be presented and demonstrated at the 2013 Weeds Conference in Corowa on Wednesday 11 September 2013 for consideration and discussion.

WEEDS TRAINING COMES OF AGE

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SUMMARY Changing priorities, skills recognition funded programs and other opportunities have led to a change in the way that weeds training is being managed by NSW Department of Primary Industries (DPI). The current suite of short courses and access to full qualifications are still available through Tocal College, however they are now administered through PROfarm rather than the Weeds Training Program (WTP). All courses are still supported by the DPI Invasive Plants and Animals Branch. Regional Weeds Advisory Committees have the opportunity to request regional training and have input into the development of training according to industry needs.

Keywords: Training, weed officers, skills recognition, qualifications

Figure 1. Graduates from the Weed Training Program (Skills Recognition); Don Mackenzie, Terry Inkson, Kim Hignall, Doug Campbell and Andrew (Advanced Diploma), Neil & Alex (Diploma) and Robert Christian (Certificate IV.)

HISTORY

The NSW Weed Training Program (WTP) began in 2000 initially promoted by Macquarie Valley Weeds Committee and Tocal College. This was the first time the skills of people working in the weeds industry were nationally recognised and professional accreditation standards provided through nationally endorsed Training Packages such as the then Conservation and Land Management Training Package.
Since 2001, 120 weeds officers have progressed from these short courses to obtain nationally recognised full qualifications for Certificate IV, Diploma and Advanced Diploma through completion of short courses and the Tocal College Skills Recognition program (Figure 1).

The WTP short courses are current and reflected best practice management. In 2012, 450 participants attended 38 courses on 14 different topics (Figure 2).

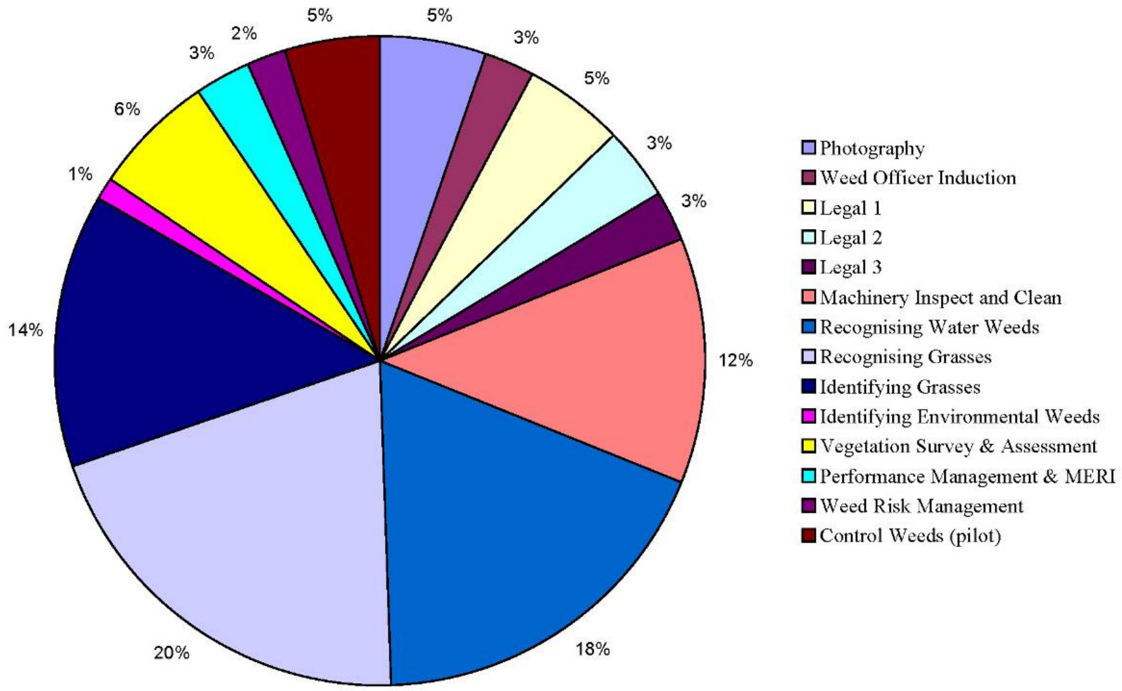

Figure 2. Percentage of participants attending different WTP courses in 2012.
Notes: (Legal 1, 2 & 3 courses are the minimum legal training needed by weeds officers – giving 3 units of competency) (MERI – Monitoring, evaluation reporting and improvement).

FUTURE

Changing opportunities and a drive to increased efficiencies means a new approach to delivery of weeds training for NSW commenced in 2013. Rather than all courses being managed by the Weeds Training Program, weeds training is now integrated with DPI short course delivery under the PROfarm banner (Figure 3).

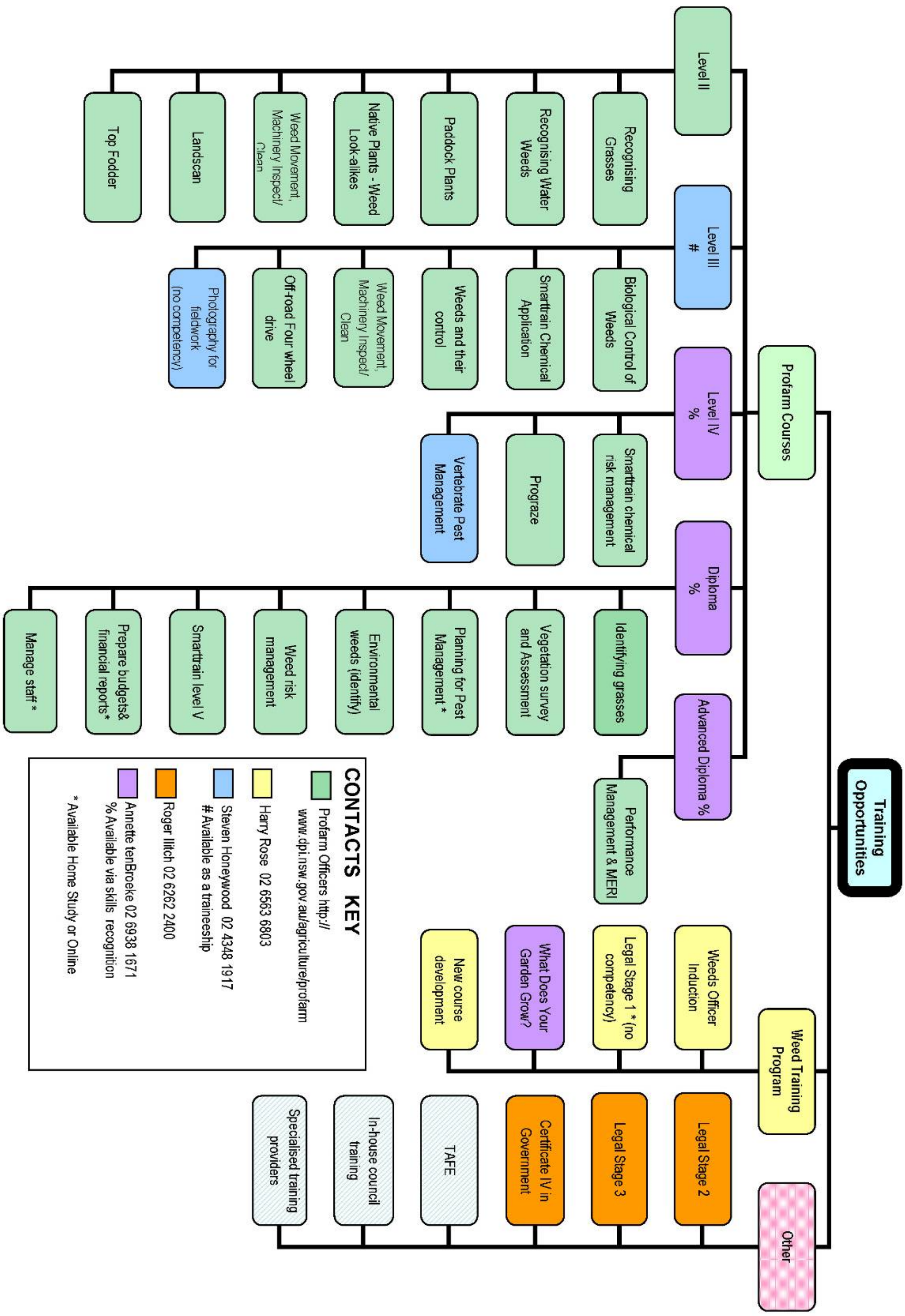

Figure 3. Weed-related training opportunities available through PROfarm, Weeds Training Program and associated organisations.

New and up-to-date weeds training resources will continue to be provided by DPI and weeds training will continue to be promoted through the existing Weeds Extranet, with the Weeds Training Coordinator (Harry Rose) concentrating on the Weed Officer Induction program, Legal 1 training and development of new courses. The Coordinator will not manage registrations for other courses, this will be the role of PROfarm. PROfarm now offer a one-stop shop for more than 100 weed and agricultural related courses .

Thus the process for registering for courses will be the same as it has been for SMARTtrain chemical accreditation, Biological Control of Weeds and Off-road Four Wheel Drive (4x4) training. The only courses which can't be accessed through PROfarm are Legal 2 & 3, which are now run by the Australian Centre for Environmental Compliance. Information and registration for these courses can still be accessed through the Weeds Extranet and DPI's Weed Management Training pages, while DPI staff will continue to provide in-course support.

Courses will also be promoted through the PROfarm website and PROfarm coordinators who are located throughout the State. The PROfarm coordinators are located regionally and are responsible for developing the calendar of courses in their area. Hence, the old WTP weeds training calendar has ceased production to avoid duplication and confusion.

It is critical the Regional Weeds Advisory Committees discuss the anticipated requirements and timing for courses in their region with the PROfarm coordinators and assist them to promote the courses to ensure the minimum numbers are achieved and industry needs are met.

Figure 4. Participants involved in Certificate ll to Advanced Diploma training offered by PROfarm; Recognising Water Weeds, Vegetation Survey & Assessment and Performance Management & MERI.

FLEXIBLE TRAINEESHIPS

The Tocal College flexible traineeship program will continue to operate to support new entrants to the weeds industry. Employer incentives and fully funded training for Certificate III in Weed Management and Certificate III in Conservation and Land Management (CLM) are available year round for traineeships.

Next year will see major reform to the structure of traineeships and other funded training with the introduction of the NSW Smart and Skilled. As these changes emerge we will advise the industry of any impacts and opportunities. Tocal College will continue to seek funding for weeds industry training and alert the industry to available funded training and assessment programs.

SKILLS RECOGNITION

Opportunities for Skills recognition and obtaining full qualifications through Tocal College remain unchanged and are available throughout the year.

There are several ways weeds officers can obtain full qualifications at Certificate IV, Diploma and Advanced Diploma level. Some of the units are available through the short course program that has already been discussed. Some are available via on-line courses (Home Study).

When clients feel they have achieved a particular level of skills they can apply for Skills Recognition. The most common way the qualification is obtained is through the candidate gathering together their evidence and answering questions on the Units of competency selected and bringing these to a “skills recognition interview”. Up until 2013 funding for this has been available and this made it a very attractive option. With the scarcity of funds and for those who are very organised, a cheaper option is to present this case in writing by what is called a “desk audit”.

Qualifications currently available include:

- Certificate IV in Conservation and Land Management
- Diploma in Conservation and Land Management
- Diploma in Pest Management
- Diploma in Community Coordination and Facilitation
- Advanced Diploma in Conservation and Land Management.

CONCLUSION

While some changes have occurred, the NSW weeds industry will continue to be well supported for their training and assessment requirements through the Invasive Plants and Animals Branch, PROfarm and Tocal College. We will continue to work with the weeds industry to meet changing and emerging needs with relevant, quality training programs.

ACKNOWLEDGMENTS

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NSW WEEDS ACTION PROGRAM
Where it came from;
Where it is now;
What is in the future?

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SUMMARY The NSW Weeds Action Program (WAP) is a major change to the way weeds management was financially supported across NSW. The WAP has challenged entrenched funding models as well as "traditional" weed management paradigms at all levels. The WAP has also tested the results of a number of previous programs and the relationships between people at all levels. Even given the radical nature of the changes, the WAP has been almost universally embraced and the results from the first two years effort are impressive. Additionally, some partners are already looking to the future and taking their projects to the next level.

Keywords: Change, partnership, support.

INTRODUCTION

While the Weeds Action Program (WAP) seemed to appear out of thin air, this was far from the case. In fact it was the culmination of a number of years of seemingly unconnected changes and programs. Decreasing resources and increasing demand and accountability were not the least of these, but it is the institutional changes that were the key drivers of change.

Weed management generally had been shifting focus and strategies for a number of years. For example, it had moved progressively from simply agricultural-based weeds to include environmental weeds; it was changing from the paradigm of chasing all weeds all the time towards prioritising and addressing introduction, establishment and spread processes. This shift was crystallised in programs and plans such as the National Weeds Strategy, first implemented in 1997, the Weeds of National Significance program initiated in 1999, and the later National Weed Awareness campaign.

Change in the way we choose to manage invasive species is inevitable, as is illustrated by the current move towards holistic Biosecurity models for all pest, disease and invasive species management. The WAP will also need to evolve to meet the future challenges and to remain a significant leader and driver for invasive species management in New South Wales (NSW).

This paper will explore the climate that instigated the WAP, where it is at in time and process, what it has changed and what is possible for the future.

CONCEPTION OF THE NSW WEEDS ACTION PROGRAM

To understand the NSW WAP, it is important to understand the key policy drivers that led to its implementation and the basic hierarchy in which WAP sits.

The *Australian Weeds Strategy (2006)* (AWS, NRMMC, CA 2007), provides the nationally agreed framework that guides all parties towards cooperative and consistent weed management.

The AWS vision statement is that "*Australia's economic, environmental and social assets are secure from the impacts of weeds*"

The *NSW Invasive Species Plan 2008-2015* (ISP, NSW DPI 2008) is the NSW Governments' plan for coordinated response to invasive species in the state, including vertebrate and invertebrate pests and weeds. The ISP is informed by a number of plans, strategies and legislative instruments, one of which is the Australian Weeds Strategy.

The ISP vision statement is that "*The environment, economy and community of NSW is protected from the adverse impacts of invasive species*".

Both of the above documents articulate the key goals now commonly accepted as necessary for effective weed management, these being to:

1. exclude/prevent new weed problems;
2. eradicate or contain new species;
3. effectively manage/reduce impacts with prioritisation of actions; and
4. capacity build and to ensure we have capacity to manage weeds.

The WAP is the whole of NSW Government approach to providing grants to assist a range of organisations in implementing the weeds components of the ISP. The WAP is the result of a weed management transition process over a number of years. This change is part of a global paradigm shift and has been driven by many factors including economics, better weed science, community attitudes, politics, land use change, technology, education, and so on. In short, as the world changes, weed management expectation and techniques change with it.

The situation with NSW and the WAP is part of this global change, but for the purposes of this paper we will only discuss the internal (NSW) factors that led directly to WAP.

EVALUATION OF PROJECTS

In 2003-2004, DPI started a project (the Performance Management Project) to evaluate what was actually happening with grants, what was being reported, whether the information we were requesting was meaningful and what were meaningful measures of success in weed management. The project also researched a wide range of literature and programs in other jurisdiction to find out what they were doing.

It is important to remember that the factors discussed above directed us to address the impacts of weeds, not just their presence.

The final report from the project was lengthy and complex, but the basic result was that we were not measuring anything really meaningful but, more interestingly, no one else was either. There simply were no real measures of success in weed management (reduced impact) available other than very long-term and expensive resource monitoring programs.

The time and cost required to measure long-term weed management changes is simply too great to satisfy the reporting needs of the funding organisations which work on very short timelines including those related to financial year, election term and other considerations. So, while we have implemented long-term monitoring programs, we have asked to report on short term indicators in the interim.

CHANGED REPORTING

As a result of the Performance Management Project, a new policy covering reporting on noxious weed grants was put in place. The core principles are that:

- DPI will provide the framework for the implementation of performance measurement principles in all reporting obligations including the noxious weeds grant under section 37 of the *Noxious Weeds Act 1993*;
- all noxious weeds grant projects will include performance measurement principles using standard reporting methods;
- DPI will support 3-5 year planning cycles for noxious weed grant projects;
- all regional weed strategies supported by noxious weeds grants will include key performance indicators.

There were also a few other principles that are not a written part of the policy but that are important in devising a monitoring and reporting process, these being that:

- monitoring and reporting a part of good weed management practice;
- monitoring and reporting should be cost effective and not require excessive financial input;
- monitoring should not require excessive resourcing and should be able to be undertaken in the course of normal daily duties;
- monitoring and reporting should also meet the needs of the reportee (where-ever possible); and
- data collected should be usable across a number of reporting requirements so that is only needs to be collected once.

NOXIOUS WEED GRANTS

A noxious weeds grant, in one form or another, has existed in NSW since 1963: the process has distributed over $193 million to authorities across NSW. Up until 1999, almost all of this was provided to individual organisations for localised projects.

For the financial year 1999 – 2000, the grant funded 279 separate projects; 238 (88% of budget) were to local projects and only 46 (16% of budget) were for regionally coordinated projects and planning.

The 1999 – 2000 grant process saw a few apparently minor, but significant changes begin to gather momentum. These included that:

- Regional Group Projects involving multiple partners across broad geographical areas were encouraged;
- grants were provided to assist the emerging Regional Weeds Advisory Committees (RWAC's) as coordinating groups for complimentary programs across control authority boundaries;
- specific grants were provided to assist the "Regions" to develop regional weed plans and strategies and
- a weeds training and skills development program for weed officers was instigated.

In 2000-2001 further changes were implemented, such that:

- the "Inspectorial" grants ceased and were replaced by Weed Control Coordination (WCC) grants – these now included inspectorial, partnership and capacity building functions and activities. WCC grants were also “benchmarked” to set minimum standards of cover in each LCA;

- further funds were allocated to encourage the formation of cooperative arrangements amongst LCA’s;
- Regional Group project numbers increased to 71;
- Local Weed Control Projects reduced to 79;
- the total number of operational grants to separate organisations reduced to 201 including those for State Priority species; and
- the first Regional Project Officers were funded.

By 2009-2010 the grant mix was radically different to that before 1999 in that there were:

- 97 Weed Control Coordination grants totalling $5.3 million (43% of budget);
- 69 Regional Group Project grants totalling $1.86 million (21.8% of budget);
- no Local Weed Control projects;
- 21 State Priority species projects totalling $776,000 (9.1% of budget);
- increases in the training budget from 0.6% to 4.3% of the total grant amount; and
- RWAC’s and Project Officers well entrenched as key components of the NSW weed management structure.

It is obvious from the above transition that there was a deliberate shifting of resources and activities towards more strategic projects, and collaboration between partners in more effective broad scale programs. As a result, there was a fundamental shift in Weed Officers roles from simple inspectorial activities towards planning, strategy development, community education and capacity building, and cross jurisdictional liaison. The weeds education program played an essential role in the officer’s personal and professional development and their standing within their own and other organisations.

Even with these changes, the Weeds Grant Programs in place up until 2009-2010 had a number of inherent faults for both the recipient and the provider in that:

- there was an unnecessarily complex and time consuming administration process with large numbers of applications and reports;
- every application was processed in hard copy resulting on over 3,000 document movements annually;
- the distribution of grants was still too fragmented to allow a fully integrated program.
- there was little recognition of the concept of the grant creating a partnership;
- the program was functionally too inflexible and was not adaptive and responsive;
- the program did not recognise (or trust) the recipients capacity to be adaptive and responsive;
- the AWS and ISP were not entrenched in the program;
- the program did not encourage innovation, leadership or ownership by all parties; and
- it was still considered by many as a “grant by right” rather than one that had to be competed for, justified and properly reported.

WHAT IS THE NSW WEEDS ACTION PROGRAM (WAP)?

The WAP is the response to all of the above drivers and pressures. It is simple in its operation and radically different in how it works, how it is applied for and how it is reported to the Weeds Grant Programs.

The WAP's conception was much longer than its incubation and its birth and it was not full formed when first delivered. In 2009 when WAP was announced, there had been a period of change within Governments and councils, as well as in the legislation, the ISP was announced, and each region had an agreed, cooperative Regional Weed Strategy in place. This climate offered a small window of opportunity in which something new, although not entirely unexpected and different, could be introduced.

In moving to the WAP there had to be recognition that the ISP required a much broader approach to weeds than that previously applied: the WAP needed to be a "weed" program, not just a "noxious weed" program. Consequently, local governments, if they chose to participate, were going to be asked to take on activities that were outside their legislative functions. This broadening also necessitated building partnerships with community and other organisations that had not necessarily been part of the traditional noxious weed world.

It was also evident that the NSW Government needed to make certain things happen and that these were not all statutory functions or responsibilities of recipients. In order to implement the ISP it was essential that the program was implemented on a purchaser/ provider model; in essence, the NSW Government would be purchasing ISP implementation and outcomes from the providers.

The main components of the WAP

- It is focussed fully on implementation of the ISP. All activities in the project submission must clearly link to an ISP goal, objective, action and outcome – either directly, or through corresponding parts of their regional strategy.
- Projects could only be on two levels, State Projects and Regional Projects.
- Regional projects are based on Regional Weeds Advisory Committee regions. There are no longer local projects for individual applicants. Any such activities must be incorporated into a regional submission.
- Projects are to be for a minimum of 3 years and a maximum of 5 years.
- Submissions are only required at year 1, instead of annually as previously required.
- Partnerships are essential. The more active partners in a project the more likely it is to succeed.
- Mandatory outcomes were prescribed for the first 2 years. Essential components of the ISP relating mainly to identification of high risk species and planning for their management are also required to be implemented.
- The submissions are entirely electronic, requiring only a cover sheet to be signed and submitted separately.
- Each outcome has one or more activities listed against it. Each activity has a target which is always a number. The targets are what are reported on.
- The submission form includes the reporting forms which are automatically populated from the inputs, that is the actions and outcomes are populated on multiple sheets after being entered once.
- Reporting followed a "deviation reporting" model. If the target number has been met then the report only shows that fact. If the target has not been met, and the deviation is greater than 20% then that deviation must be explained and measures put in place to rectify this in the following year.
- Projects are species- and tenure-neutral. The WAP is about outcomes, not which species are being treated on what land. Too many specifics tying funds and people to absolute actions is contrary to the need for flexibility.
- The WAP does not focus a lot of "hows", rather it looks for "whats". If the applicant needs to do a certain thing to implement their project then this is their call. It is

potentially possible for a WAP recipient to contract out all their work (but they are still responsible for its outcomes).

- Despite recipients being legally contracted to implement the project as described, it can be varied by mutual agreement if sufficient justification exists.

The WAP is built on trust and confidence in the recipients. There is not enough information and detail in the submission for absolute certainty, nor can there be. The WAP offers opportunities for a region to build their weed program to suit themselves provided the outcomes are effectively met.

What is in place today?
The full information on what is actually in place under the WAP at this time is available on the DPI website and the outcomes up to 2011-12 are available in the *NSW Weeds Action Program Annual Report 2011-2012*.

A snapshot of where WAP is at now is that:

- there are 14 Regional and 9 State WAP projects currently running;
- the regional WAP projects cover all of NSW and involve in excess of 200 partner organisations;
- 14 of the following regional documents now cover the whole of NSW, that is:
    - high risk species lists and high risk pathway identification lists completed;
    - new incursion management protocols and response plans are in place;
    - inspection programs have been developed and implemented; and
    - communication strategies are in place.

Example 1: 14,500 high risk sites and 191,500 km of high risk pathways covering 800,500 ha have been inspected.

Example 2: 133,000 property management plans have been developed, there have been 41,000 inspections on private lands, 240 weed related communication events, and over 2000 media articles.

Over $27 million in NSW Government funds have been allocated to this time, but this amount has been more than doubled by partner organisation contributions. The NSW Weeds Action Program has (almost) universal acceptance and support.

WAP INTO THE FUTURE?
The current WAP is designed to be a 5 year program concluding in June 2015. The intent is that the program will be reviewed and evaluated at this time to determine its successes, failures, strengths and weaknesses so that the next round can take a further forward step. Obviously, in order to avoid a time gap between this and the next WAP, some pre-emptive evaluation and development must commence now.

The Invasive Plants and Animals Branch have discussed “WAP 2” briefly and informally as a preliminary to this revision. Essentially, we cannot see a need for radical change, but we do agree that WAP must keep moving forward. We need to build on the strengths of the program and the change that “WAP 1 created”, and to take the next step/s. In particular is essential that the developing partnerships in the program are enhanced and improved on, as these are our greatest strength. Part of the revision will be to include these partners in the new development process.

Change is still ongoing and the next few years will not be an exception; there are several significant changes happening right now that most will be aware of:

- Local Lands Services (LLS) are expected to be in place by January 2014. The LLS will be a compilation of the Catchment Management Authorities, Livestock Health & Pest Authorities and much of the extension and advisory services previously provided by DPI. While it is mooted that the LLS's will have an increased role in weed management, this has not yet been defined;
- Biosecurity NSW is a fact. It includes all functions related to the management of risks to the economy, environment and the community from pests and diseases, invasive plants and animals, and chemical contaminants. This includes all the tasks and activities of the DPI Invasive Plants and Animals group and, by default, those of the local control authorities and LLS's related to weed management;
- A NSW Biosecurity Strategy is currently in preparation and will be the overaching position for NSW on Biosecurity matters. Biosecurity is about risk management. The broad goals for the Biosecurity strategy in NSW are to manage pest, weed and pathogen risks by:
  - preventing their entry into NSW;
  - quickly finding, containing and eradicating any new entries; and
  - effectively minimising the impacts of those pests, weeds and pathogens that cannot be eradicated.
- New Biosecurity Legislation is currently in a scoping phase. It is intended that a single "Biosecurity Act" will replace most or all of the current legislation covering pests and weeds, including the noxious weeds legislation. It is likely that this new legislation will be significantly different in its approach and operation from what we have now.

Governments will change, budgets will change, knowledge will change, technology will change and the people involved will change. We deal with these things every day and have done in the various grants schemes since their inception 60 years ago.

The WAP will also change after 2015, just the same as it has in the brief time since its introduction. The first round of the WAP was always intended to be flexible and evolutionary, adapting as the partners involved adapted, learned and evolved their capacity through its implementation.

We are more than well positioned to accept the changes and challenges ahead. There is little in the proposed directions, goals, objectives and actions that we are not already doing under WAP, indeed, the WAP partnerships are well ahead in much of what is proposed.

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FURTHER INFORMATION

NSW Weeds Action Program Guidelines.

Contact the relevant local Invasive Species Officer at the New South Wales Department of Primary Industries. http://www.dpi.nsw.gov.au/agriculture/pests-weeds/weeds/contacts

FUTURE OF WEED MANAGEMENT IN NSW

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SUMMARY While the new LLS regional organisations will not initially have responsibility for weed management, they will play a major role in broader biosecurity and there is a big push for them to take over weeds in the future. However there is still a great deal of uncertainty around these new organisations (that are supposed to start operations at the beginning of 2014).

EARLY DETECTION AND MANAGEMENT OF WATER STARGRASS (HETERANTHERA ZOSTERIFOLIA) UNDER THE NEW SOUTH WALES WEEDS ACTION PROGRAM (WAP)

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SUMMARY Under the New South Wales Weeds Action Program (WAP), Port Macquarie-Hastings Council (PMHC) routinely inspects and treats prescribed incursion pathways for noxious and other high-priority invasive weeds. In 2011, under an interdivisional cost-sharing arrangement, a new weeds officer position was created with the purpose of helping the organisation meets its new obligations under the WAP to locate and treat priority weeds, achieving the dual benefits of asset protection and weed management. The organisation manages significant infrastructure assets which, in turn carry equally significant pest plant liabilities, and it is through this cost-sharing arrangement that 'two birds might be killed with one stone'.

In late 2011, during a routine urban stormwater drain inspection in an industrial area, an unknown plant was noted growing amongst other aquatic native vegetation. A specimen was taken and sent to the Sydney Royal Botanical Gardens Herbarium for positive identification. The plant was provisionally identified by the weeds officer as water stargrass (*Heteranthera zosterifolia* Martius, C.F.P. von), at that time and still believed to be the only known naturalisation in Australia. The Herbarium later confirmed this identification. Water stargrass belongs to the family Ponteriacea that includes other invasive aquatic plants including *Eichornia crassipes* and *Heteranthera reniformis*) and this fact combined with its obviously invasive behaviour, provided an ideal trigger for applying best practice 'early detection and management'. The decision to take on the plant was an easy one as it ticked many of the boxes which the organisations' natural resources staff are committed to, as well as clearly aligning with the stated objectives of the WAP. Operations to remove the plant commenced in January 2012 and to date have included wide-ranging integrated weed management practices including a monthly inspection regime. However, the plant is proving difficult to control and other, perhaps novel, techniques will inevitably need to be considered.

Keywords: Incursion pathways, herbarium, naturalisation, aquarium species.

INTRODUCTION

Water stargrass is grown as a relatively popular aquarium plant in Australia and other parts of the world. This native of South America (i.e. southern Brazil, Bolivia, Paraguay, Uruguay and northern Argentina) was recently recorded becoming established outside cultivation for the first time in Australia in December 2011 when a single infestation was recorded in an open drain in the industrial area of the Port Macquarie district on the north coast of NSW. This non-potable stormwater drain carries hard surface run off from the industrial area and surrounds and forms a significant tributary to the Kooloonbung Nature Park.

This species is a long-lived plant capable of growing underwater or above the water surface. Young plants usually begin life underwater and form a basal rosette of narrow leaves. When viewed from above, these plants are star-shaped and grass-like in appearance, hence the common name water stargrass. Plants are usually rooted in mud and often form very long running stems with widely spaced leaves when growing underwater, but the stems break easily and may sometimes also be found floating near the water surface.

Plants can reproduce by seed or by pieces of stem that will readily take root when conditions are suitable. They are most likely to be initially spread by the dumping of aquarium waste in wetlands and waterways. Once present in natural areas, seeds or stem segments can be spread downstream during floods or inadvertently transported to new areas by people (i.e. on vehicles, boats or shoes).

Like its close relative Kidneyleaf Mud-Plantain, water stargrass has shown the capacity to form dense mats of vegetation in wetlands. If left uncontrolled, it may eventually replace native species, decrease water quality and restrict water movement. Subsequently, the control of this species was identified as a high priority for Port Macquarie-Hastings Council.

MANAGEMENT METHOD

After discovering the aquatic plant in December 2011 Council staff sought species confirmation from the Sydney Royal Botanical Gardens Herbarium and John Hosking from the Department of Primary Industries.

Once species identification was confirmed, staff undertook immediate action in January 2012 to remove the weed from the open drain using a 25 tonne excavator. To impede fragment spread booms where placed downstream of the infested area. The dredged vegetation was removed and transported immediately from site to a vacant block of land where it was foliar sprayed with a combined mixture of metsulfuron-methyl 6oo g/kg @ 10g/100L and glyphosate (aquatic) 360 g/L (present as the isopropylamine salt) @ 1:100 utilising APVMA permit 9907 to guarantee a total kill of all removed vegetation.

One week following excavation the drain was then treated with a foliar application of glyphosate (aquatic) 360 g/L (present as the isopropylamine salt) @ 1:100 to ensure that any remaining floating fragments were treated. The growth habit of water stargrass means it is difficult to control with foliar application as some individuals present as an attached emergence however some of the population actively grow fully submerged. During this treatment phase small populations of rooted submerged water stargrass were identified within the excavated area. The entire drain was then inspected for any new infestations and these individuals were dug up by hand and removed to quickly control any further spread. Following primary control, a monthly inspection and foliar spray program with glyphosate was implemented to suppress regrowth, with the aim of restricting the expansion of current colony. This has the added benefit of preventing flowering and seeding therefore reducing the risk of further spread off-site.

RESULTS

A year after implementing the primary control and follow up program water stargrass aggressively persists in the drain. As expected, the primary method of control (excavation) removed a large biomass, however it also removed competing vegetation leaving a bare clay substrate which presented ideal conditions for the ongoing propagation of the remaining fragments. Consequently, a monthly inspection and control program has continued.

The follow up control method of a foliar spray with glyphosate (aquatic) @ 1:100 has so far only been able to contain and suppress the remaining specimens given that a large portion (>25%) of the foliage remains submerged. However, without continuous control it is evident that the water stargrass would return to its invasive state in a short period of time.

Given that eradication of new and emergent weeds is the desired outcome for Port Macquarie-Hastings Council, new methods are currently being researched and trialled. One method currently being trialled is light exclusion, which aims to inhibit photosynthesis.

DISCUSSIONS

Water stargrass was found growing in an industrial stormwater drain as a result of systematic mapping of predetermined incursion pathways within the PMHC LGA. This clearly shows the WAP, together with the appointment of invasive weed species Field Officers is combining to effectively and efficiently identify and control new and emerging weed species, which in this instance is particularly important given the invasiveness of water stargrass.

Its presence could be due to inadvertent dumping, aquatic green waste disposal or intentional planting for propagation and potential harvest.

Given this scenario, the Australian Quarantine and Inspection services (AQIS) Weed Risk Assessment (WRA) should be upgraded to have potential importers prove a plant species is incapable of naturalization. In the meantime an educational program should emphasise the environmental responsibilities of aquatic plant ownership.

With the mechanics now in place to identify and attempt to control new and emerging weed threats there is an immediate need to improve existing frameworks to speed up the declaration status of these problem plants.

ACKNOWLEDGEMENTS

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STRATEGIC WEED MANAGEMENT IN PROTECTED AREAS OF NEW SOUTH WALES

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SUMMARY The New South Wales (NSW) Office of Environment and Heritage (OEH) plays an important role in weed management. OEH is responsible for the development, coordination and reporting of state-wide strategic initiatives to reduce the impacts of weeds on biodiversity, including weed Key Threatening Processes listed under the NSW *Threatened Species Conservation Act 1995* (TSC Act). OEH also plays an important role in the Weeds of National Significance initiative and, as part of this, two National Coordinators are based at OEH. In addition, the National Parks and Wildlife Service (NPWS) sits within OEH and manages protected areas reserved under the NSW *National Parks and Wildlife Act 1974*. These areas cover approximately 9% of the state (over 7 million ha) and protect and conserve significant natural and cultural heritage. All NPWS weed programs are outlined and prioritised in Regional Pest Management Strategies. Weed management on NPWS estate aligns with the NSW Invasive Species Plan. Eradication, containment and/or asset protection programs are developed depending on the stage of invasion, distribution and impact of the weed(s). Weed management is prioritised through tenure-blind weed risk assessments, often performed with the NSW Department of Primary Industries (DPI).

Keywords: National parks, orange hawkweed, ox-eye daisy, regional pest management strategies, WoNS.

WEEDS AS KEY THREATENING PROCESSES (KTPs)

A threat can be listed under the NSW TSC Act as a *Key Threatening Process* if it adversely affects threatened species, populations or ecological communities or if it could cause species, populations or ecological communities that are not threatened to become threatened. There are several groups of weeds listed as KTPs:

- Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants
- Invasion of native plant communities by exotic perennial grasses
- Invasion and establishment of exotic vines and scramblers
- Invasion of native plant communities by bitou bush/boneseed (*Chrysanthemoides monilifera* (L.) Norl.)
- Invasion, establishment and spread of lantana (*Lantana camara* L.)
- Invasion of native plant communities by African olive (*Olea europaea* subsp. *cuspidata* (Wall. ex G.Don) Cif.)
- Invasion and establishment of Scotch broom (*Cytisus scoparius* (L.) Link).

If left unchecked, a threatening process will inevitably cause the extinction of native plants and animals, especially those that are already at risk such as threatened species. A number of weed threat abatement actions are identified in the NSW Priorities Action Statement. In addition, specific weed strategies aim to manage the impact of weeds on biodiversity, including the Bitou Bush Threat Abatement Plan (TAP – DEC 2006) and an overarching NSW threat abatement strategy known as the Biodiversity Priorities for Widespread Weeds (BPWW – DPI and OEH 2011). Because most weeds listed as KTPs are widespread and thus unlikely to be eradicated, the focus is placed on reducing the impacts on biodiversity, rather than actions solely associated with prevention, eradication or reducing spread. A tenure-blind approach is followed to compile and prioritise sites within core infestations of widespread weeds and a risk matrix is used to ensure management is targeted at sites where the biodiversity is most at risk from high priority weeds but also likely to respond to management.

The Bitou TAP is the longest running weed threat abatement strategy and a recent 5-year review showed that 157 sites have been managed along the NSW coast. During this period, stakeholders have worked collaboratively together to protect environmental assets at risk from bitou bush and to reduce the extent of bitou bush. These efforts involved a range of land managers, including the OEH (including NPWS), local government, the previous five coastal Catchment Management Authorities (CMAs) in NSW, the Crown Lands Division of the DPI (former Land and Property Management Authority), community groups, Aboriginal groups and bush regenerators. Where sufficient monitoring data existed, in most cases it showed that long term management of all weeds delivered a positive native species' response at key sites. Bitou bush density was also reduced in containment zones and the containment lines receded.

WEEDS OF NATIONAL SIGNIFICANCE (WoNS)

KTPs are also addressed through the WoNS initiative. At the time of preparing this paper (April 2013) OEH housed two WoNS coordinators who coordinated seven Asparagus weed species, bitou bush, boneseed and three broom species. OEH has been a long term partner in this cross jurisdictional initiative which has been a successful model for collaborative management of nationally significant weeds. The WoNS initiate provides strategic direction for 32 weeds/weed groups that focus on nationally coordinated research and management, supported by partners from the national to local level. Each WoNS has a national strategic plan which was developed in conjunction with national, state, regional, and local groups, ensuring objectives are relevant to all partners. Implementation of plans facilitates strategic investment in weed control, and encouraging cross-tenure partnerships to deliver actions. This process recognises that WoNS are national problems that can be most effectively addressed using a national approach that incorporates local and regional priorities to achieve long-term success (Cherry and Sheehan 2013).

NPWS REGIONAL PEST MANAGEMENT STRATEGIES (RPMS)

The NPWS within the OEH manages protected areas of NSW spanning more than 850 reserves. These areas protect and conserve significant natural and cultural heritage. One of the major management challenges for the NPWS is to reduce the impacts from introduced pest animal and weed species on park values, including impacts on biodiversity, cultural and historic heritage, neighbouring landholders, catchment and scenic values.

The *NSW 2021 – A Plan to Make NSW Number One* sets out performance targets, including a specific priority action under Goal 22 'Protect Our Natural Environment' which is to address core pest and weed control in National Parks through the delivery of RPMS (OEH 2012). In 2011/12, the RPMS were updated following a series of regional pest forums. Weed programs in the RPMS align with the NSW Invasive Species Plan (DPI 2008), with eradication, containment and/or asset protection programs developed depending on the stage of invasion, distribution and impact of the weed(s). The RPMS has four categories for critical priority weed programs, being: 1) *Threatened Species Conservation* for programs targeting weeds which are, or are likely to be, significantly impacting on threatened species/populations/communities; 2) *Health and Disease* programs that target weeds which impact significantly on human health or are part of a declared national emergency; 3) *Economic* programs targeting weeds that impact significantly on economic enterprises; and 4) *New and Emerging* programs addressing new occurrences or suppressed populations of highly invasive weed species with potential for significant impacts.

As part of the RPMS revision, the prioritisation framework within the BPWW was used to select sites for management for *Threatened Species Conservation*. Therefore, sites where widespread weeds are impacting the biodiversity within NPWS reserves have been systematically identified and prioritised using the triage approach that considered the biodiversity at risk and the likelihood of achieving a positive biodiversity response.

NPWS also manages a number of new and emerging weeds. The information below details the approach for two of these critical priority programs in the Southern Ranges Region, orange hawkweed (*Hieracium aurantiacum* L.) and ox-eye daisy (*Leucanthemum vulgare* Lam.). Another paper in these proceedings details the program for carrion flower (*Orbea variegata* (L.) Haw.) in the Northern Plains Region (Hamilton *et al*. 2013). Of these only orange hawkweed is listed as a Noxious Weed. However, experiences from other states or countries as well as recent research and Weed Risk Assessments undertaken jointly by OEH and DPI suggest that all three weeds threaten biodiversity and could cause future environmental damage. These weeds also have the potential to seriously impact Australia's pastoral industry.

ORANGE HAWKWEED AND OX-EYE DAISY

Orange hawkweed has the potential to become a serious weed in south-eastern Australia. It is a major weed in other countries and is on the National Alert List for Environmental Weeds, a list of 28 non-native plants in the early stages of establishment that have the potential to become a significant threat to biodiversity. Although a major threat to biodiversity, should hawkweed reach its potential distribution, the loss to the Australian grazing industry was predicted (in 2002) to be approximately $48 million/year (Brinkley and Bomford 2002). Hawkweeds are Class 1 Noxious Weeds in NSW. Although, orange hawkweed was sold in nurseries in NSW until relatively recently (DPI 2012), it was first recorded as naturalised in 2003 in NSW (Caldwell and Wright 2011).

Currently in NSW orange hawkweed is only recorded in Kosciuszko National Park. In line with the NSW Orange Hawkweed Strategy (DPI 2012), all infestations are being actively managed with surveillance undertaken to locate outliers. The current surveillance area is large, being across 8,165 ha of remote, rugged and often heavily-vegetated parts of the Park. The difficulty of the terrain, vegetation, ambient conditions and the large surveillance area all present challenges to this program. Fortunately, the NPWS program has been supported by a large contingent of volunteers. Most surveillance for orange hawkweed must be undertaken on foot. In the previous four years, volunteer involvement contributed invaluable support with over 170 volunteers participating. Results for the 2012/13 season indicate that orange hawkweed is still only known to occur within the previous known locations. Further, its area of occupancy was <8.15 ha. These plants have been treated and no new locations have been found outside the known extent.

Although prompt treatment of known sites has limited its spread in NSW, field days have previously been conducted with neighbouring stakeholders to increase surveillance in lands adjoining Kosciuszko National Park. In addition, to raise awareness, a Flickr Site is regularly updated (http://www.flickr.com/photos/nswnationalparks/5386025760/in/set-

72157625773914379/). However, one challenge to the eradication of orange hawkweed in NSW relates to the previous nursery trade of the plant and its potential presence in gardens.

Like orange hawkweed, ox-eye daisy is also found in Kosciuszko National Park. Both weeds have major impacts in North America, with ox-eye daisy appearing to have a much greater extent. Recent University of Wollongong research suggests that the impacts of both species are similar (Rowland 2012).

Ox-eye daisy is also a garden escape and a perennial herb from Europe that spreads primarily by seed, but also by shallow creeping rhizomes. Ox-eye daisy control programs are included in several of the RPMS, e.g. Southern Ranges, Blue Mountains, Lower North Coast and North Coast, as ox-eye daisy has a wider distribution than orange hawkweed. Within northern Kosciuszko National Park, a coordinated control program is underway comprising annual mapping, herbicide control, monitoring program and herbicide trials to attempt to reign in the spread of ox-eye daisy. Cooperative ox-eye daisy control is also being coordinated with Snowy Hydro, and Essential Energy Ltd provides funds for contractors. To support management of both weeds, NPWS is also undertaking herbicide trials to increase management effectiveness and efficiencies.

NPWS PEST AND WEED INFORMATION SYSTEM (PWIS)

The NPWS has recently developed the PWIS. Pest animal and weed management programs are recorded through this system. Data captured includes the weed species targeted for management, the method and frequency of management, any biological assets the programs are aiming to protect and the cost of management, including staff time, contractor and other expenses and volunteer input. The PWIS also records the spatial extent and density of weeds as well as recording the location where management has occurred. This database will enable NPWS to report on weed management activities to our partners, including to regional weed committees and to DPI.

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Management of weeds on NPWS estate is undertaken by regional field staff, volunteers and contractors with assistance provided by dedicated Regional Pest Management Officers. Strong across tenure partnerships exist with local government, DPI and CMAs and other stakeholders. Considerable efforts from community volunteers assist with weed management.

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CARRION FLOWER, A NOVEL INVASIVE SPECIES IN NSW

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SUMMARY Carrion flower (*Orbea variegata* (L.) Haw.) is a stem-succulent, perennial herb in the Apocynaceae family. Native to South Africa and widely cultivated as a hardy, 'low-care' ornamental plant; it has naturalised in semi-arid and arid parts of Western Australia, South Australia, and Queensland. In South Australia, concerns were raised regarding the invasive potential and impact of carrion flower after it invaded chenopod and saltbush/bluebush vegetation communities. The species was found to limit the growth of *Atriplex vesicaria* Heward ex Benth. by reducing water availability. Biomass of annual plants and the number of seedlings that germinated under *A. vesicaria* were also reduced. In 2010, carrion flower was detected in north-western New South Wales (NSW) in the Gilgais region of Pilliga National Park. The known extent of the infestation is approximately 35 ha. Upon discovering the infestation, a NSW Weed Risk Assessment was performed to ascertain potential risk. This assessment confirmed that carrion flower is a 'very high risk' weed. The NSW National Parks and Wildlife Service (NPWS) immediately treated the weed to prevent further spread. This initial herbicide treatment was mostly ineffective. Subsequently, foliar application of four herbicide formulations was trialled *in situ* to determine: i) efficacy of carrion flower control; and 2) any non-target damage to native plant species. Monitoring plots were established and sampled before and after herbicide application. Interim results showed that Garlon 600 and Starane® Advanced achieved 100 and 98% mortality of the plant respectively. As yet, negligible impacts on non-target native species have been detected. Although, given some of the herbicides may have active residuals in the soil, ongoing monitoring will be necessary. Once a suitable herbicide is identified and the full extent of the infestation is adequately delimited, an eradication program for carrion flower in Pilliga National Park will be considered.

Keywords: Eradication, herbicide trial, new and emerging weeds, Orbea variegata, Pilliga National Park.

INTRODUCTION

Carrion flower (*Orbea variegata* (L.) Haw.) is a leafless stem-succulent, perennial herb in the Apocynaceae family. The plant has erect branches to 15 cm high (PlantNET 2013) that vary in colour from green and purple to less commonly yellow or orange (M Hamilton, pers. obs. 2012-2013). Flowers are star-shaped and produce an odour akin to that of rotting meat, attracting flies which are the main pollinators (Meve and Liede 1994). Each flower produces a two-pronged fruit that enclose numerous wind-dispersed seeds. The plant forms dense mats with stems that root at the nodes and spread vegetatively (Albers and Meve 1991, M. Hamilton, pers. obs., 2012-2013).

Carrion flower is native to South Africa where it grows in well-drained rocky areas (Dunbar and Facelli 1999) with winter dominant rainfall, averaging 250 to 700 mm a year (Lenz and Facelli 2003). In Australia, it is cultivated as a hardy, 'low-care' ornamental plant and was first naturalised in 1967 at Whyalla in South Australia. Infestations now exist in semi-arid and arid parts of Western Australia and Queensland but most of the distribution occurs on the Eyre Peninsula in South Australia (The Council of Heads of Australasian Herbaria 2013).

In South Australia, concerns were raised regarding the invasive potential and impact of carrion flower in chenopod and saltbush/bluebush vegetation communities. There, the species grows in the shade (root zone) of the dominant shrub, *Atriplex vesicaria* Heward ex Benth. (bladder saltbush). Carrion flower was found to limit the growth of *A. vesicaria* and reduce water availability (Dunbar and Facelli 1999). Biomass of annual plants and the number of seedlings that germinated underneath saltbush were also reduced (Dunbar and Facelli 1999).

CARRION FLOWER DISOVERED IN NSW

In November 2010, NPWS staff discovered a population of carrion flower in the Gilgais region of Pilliga National Park (NP), 45 km south west of Narrabri in north western NSW. This is the only recorded infestation of the species in NSW and the origin of the infestation is unknown. The species occurs sparsely across an area of approximately 35 hectares, though efforts are currently underway to verify this extent. Infestations seem to be limited to *Melaleuca densispicata* (Miles honey myrtle) tall shrubland and *Allocasuarina luehmannii* (Buloke) low open woodland (where *Melaleuca densispicata* Byrnes is the dominant shrub) that is interspersed with ephemeral wetlands of the Pilliga Outwash. Bell *et al*. (2012) has recommended these wetlands to be considered as endangered in NSW.

Upon discovering the infestation, a NSW Weed Risk Assessment was performed by the NPWS to ascertain potential risk and priority for management. This assessment confirmed that carrion flower is a ‘very high risk’ weed, and the management goal for NSW should be ‘eradication’. Due to the relatively small extent and the invasive potential of carrion flower, the NPWS immediately treated the weed to prevent further spread. Limited options were available to the NPWS as no registered herbicides were available for the plant. A formulation of metsulfuron methyl and glyphosate as per PER9907 were foliar applied in mid-2012. This initial herbicide treatment was mostly ineffective, resulting in some mortality, but generally most plants survived.

HERBICIDE TRIALS IN NSW

Following the unsuccessful herbicide treatment, an expert from the NSW Department of Primary Industries was consulted to determine other suitable herbicides for carrion flower. A variety of herbicide treatments effective on succulent species were recommended. Four herbicide formulations were selected to trial as foliar sprays: Garlon 600 1:60 dilution with diesel, Starane Advanced (30ml in 5L water), and Grazon Extra full (25ml in 5L water) and half strength (12ml in 5L water). Use of these herbicides on carrion flower is not permitted on the herbicide labels and no off-label permits exist for this application. However, small-scale trials of herbicides are permitted to generate data relating to efficacy. The intention is to apply for an off-label permit if suitable herbicides are identified.

To determine herbicide efficacy on carrion flower and potential non-target impact to native plant species, 25 1x1 m plots were established and 5 treatments randomly assigned to them (4 herbicide treatments and 1 experimental no spray control). In addition to observations in the smaller plots, a further five 3x3 m plots were established to determine the effect of the herbicide on the four dominant native species: *M. densispicata*, *Allocasuarina luehmannii* (R.T.Baker) L.A.S.Johnson, *Acacia havilandiorum* Maiden, and *Eremophila deserti* (A.Cunn. ex Benth.) Chinnock. In each 1x1 m plot photos were taken, the cover of live and sick foliage estimated, and the number of fruits and flowers counted. In each 3x3 m plot, photos were taken, the cover of live and sick foliage was estimated and the number of live plants counted. Pre-control sampling occurred in October 2012, herbicide treatment in November 2012, and the first post-control sampling in mid-March 2013 with further monitoring scheduled for May 2013 and thereafter.

The interim results of the carrion flower monitoring are presented in Figure 1. Starane Advanced and Garlon 600 resulted in 98 and 100% mortality of the plant respectively. The two concentrations of Grazon Extra drastically reduced cover but much of the remaining foliage was either alive or sick, and hence may regrow. The effect of the herbicide on the four native species was minimal. The smaller shrubs, *E. deserti* and *A. havilandiorum* that had foliage directly sprayed were killed but, as yet, there is no evidence of death of plants that were not sprayed directly (i.e. through soil residual uptake).

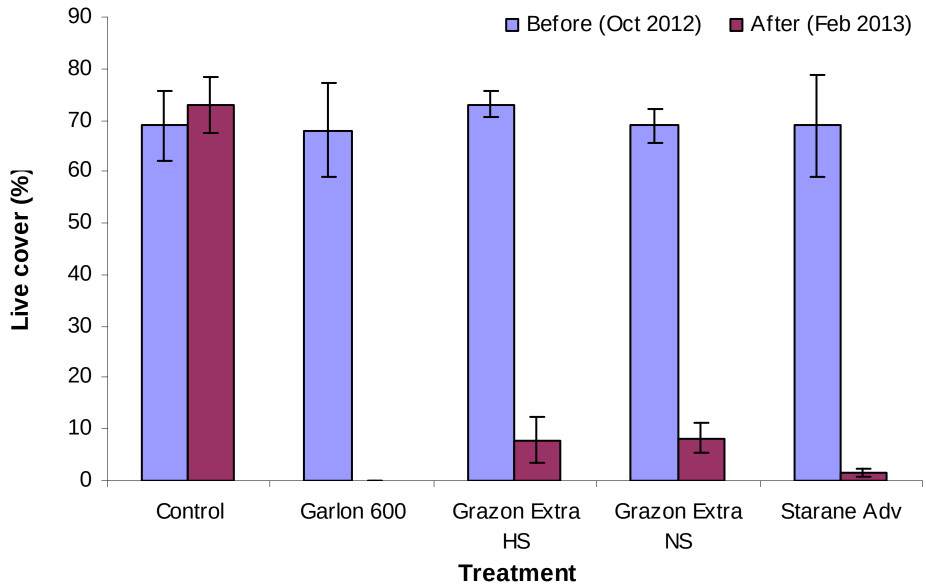

Figure 1. Live foliage cover (%) of *Orbea variegata* before and after treatment with four different herbicide formulations and no treatment control. Error bars represent ±1 SE.

DISCUSSION

Interim results indicate that Starane Advanced and Garlon 600 are most effective in controlling carrion flower, with no off-target damage to the dominant *M. densispicata*. The four herbicide treatments, however, have the ability to have soil residual impacts, particularly Garlon and Grazon and monitoring will continue to determine: i) potential non-target impacts to native species, particularly the dominant *M. densispicata* shrub; and ii) impacts to surviving carrion flower adult plants and germinating seedlings.

The results presented here are particularly encouraging considering the difficulties with control experienced in South Australia (Honan 2006; DWLBC 2013; EPNRMB 2013). It is possible that the species experiences better growing conditions in NSW, and hence better uptake of the herbicides, compared to the arid Eyre Peninsula. For a similar reason, it is speculated that the mid-2012 treatment was too late in the season for the herbicide to be effective. The species is known to enter a state of dormancy in colder months (EPNRMB 2013), which may in part explain the poor initial response to the herbicide in NSW. Interestingly, rainfall over the 4 months preceding the November 2012 treatment was up to 51% below average but approximately average in the 3 months following the treatment.

Observations in the Pilliga NP reveal that carrion flower has a strong tendency to grow under *M. densispicata* and to a lesser extent *A. luehmannii*, where cover is close to the ground or fallen timber yields shade. Very few plants grow in direct sunlight, and where they do, colouration is mostly purple. Infestations in Whyalla also have a tendency to grow in the shade of shrubs, particularly *A. vesicaria*. Lenz and Facelli (2003) showed that the reduced light and temperature under shrubs are the main facilitative mechanisms for carrion flower. Seedling survival and growth of existing plants increased in the shade, and plants exposed to greater light levels showed greater levels of anthocyanin pigments, consistent with infestations in the Pilliga (M Hamilton, pers. obs., 2012-2013). It appears likely that *M. densispicata* fulfils a similar facilitative role to that of *A. vesicaria* in South Australia and possibly that carrion flower may have the same impact on *M. densispicata*. Silcock and Page (2007) consider *M. densispicata* a rare species that performs an important ecological role by trapping both water and nutrients that then creates favourable microclimates for plant germination and growth. This seems to be the case in Pilliga NP, where species diversity is markedly higher under these shrubs, including unusual crusts of *Cladia retipora* (Labill.) Nyl. lichen (M Hamilton, pers. obs., 2012-2013).

The carrion flower infestation in Pilliga NP appears to be in a confined area. The observed responses to the trialled chemical controls indicate that herbicide treatment may be a feasible treatment option. Monitoring to determine carrion flower abundance from both existing plants and germinated seedlings, and to verify the absence of non-target damage, particularly to the important community dominant *M. densipsicata*, will continue. When suitable herbicides are identified and the full extent of the infestation is adequately delimited, an eradication program for carrion flower in Piliga NP will be considered.

ACKNOWLEDGEMENTS

The NSW NPWS at Baradine is thanked for providing vehicles and staff to assist in treatment and monitoring activities. Thanks go to Lisa Montgomery for initial efforts to identify the species, Leonie Whiffen for carrying out the weed risk assessment, Tony Cook for advice on herbicide formulations, Duane Shawcross for delimiting the infestation in the field, and Peter Berney for comments on the manuscript.

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LOCAL WEED CONTROL PRIORITISATION MAPPING

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SUMMARY Palerang Council, like most local weed control authorities, faces the increasing challenge of weed management with limited resources. The project reported in this paper refined the local land use map and applied the NSW Weed Risk Management System to determine management categories for important weeds across the Palerang area. The weed management requirements for each property were then assessed to develop an inspection regime to help prioritise Council's inspection program.

Keywords: Risk assessment, mapping, land use.

INTRODUCTION

Palerang Council has about 5 000 rural and rural-residential properties across 5 000 km^2 of diverse ecosystems. Two thirds of the area is productive agriculture land or conservation reserves and more than one hundred threatened species and ecological communities have been recorded. In order to prioritise the limited resources for weed management, Council has developed detailed weed management maps at the local level to improve its weed control and compliance enforcement policies and plans.

METHODS

Land use map

A digital land use map was created for the Palerang Local Government Area based on version 7 of the Australian Land Use and Management (ALUM) classification scheme (ABARES 2011). Spatial datasets referenced included: NSW Landuse (OEH 2011), current NSW national parks and reserves (OEH 2012), aerial photography mosaics, and the local cadastre. The digital mapping was completed as a desktop procedure with assistance from on-ground knowledge of local weeds officers.

The following major land use classes were mapped:

1. 'Nature conservation' (ALUM code 1.1), derived from the existing national parks and reserves digital layer (OEH 2012);
2. Agricultural production areas, excluding grazing (ALUM codes 3.3, 3.4). These were manually digitised over the air photo mosaic: apart from a few horticultural sites, the broad acre cropping is generally ad-hoc in suitable years and more practically grouped with grazing for long term weed management purposes;
3. 'Urban residential' (ALUM code 5.4.1) areas were derived from the NSW Landuse map with limited editing based on air photos and local knowledge;
4. 'Rural residential without agriculture' (ALUM code 5.4.3) areas were mapped based on the remaining properties with less than 10 ha of grazing land. It was considered that these properties were unlikely to have any commercial agricultural activities unless they contained patches already mapped as horticulture;

5. The dominant agricultural areas were classified to distinguish between commercial grazing and hobby farming. The distinction was based on the definition that 'Rural-residential with agriculture' was sub-commercial hobby farming, with agriculture unlikely to be the primary source of income. As it is generally accepted that a minimum of 600 ha is required for economic sustainability of a grazing enterprise in this area (Palerang 2008), it was decided that:

a. 'Grazing modified pasture' (ALUM code 3.2.1) had to have at least 300 ha of grazing land such that grazing agriculture was likely to be the primary source of income; and
b. 'Rural residential with agriculture' (ALUM code 5.4.2) had a property size more than 10 ha, with less than 300 ha of grazing land.

To map the above two classes the cadastral lots layer was merged based on ownership so that property owned by one landholder became a single spatial record. This layer was then clipped by the 'grazing modified pasture' (ALUM code 3.2.1) area derived from the existing NSW land use map (OEH 2011) to remove the non-grazing (e.g. forest) parts of each property. The resulting map of grazing land per landholder was then divided into properties with either more or less than 300 ha of grazing land.

Other land use classes with minimal extent across the Palerang area, including plantation forestry, transport and other corridors, mining, waste treatment and effluent, and water, were not initially mapped and will be added later.

Weed risk assessment

A local weed risk management assessment was undertaken using the NSW Weed Risk Management System (Johnson 2009) and templates containing information for common weeds provided by NSW Department of Primary Industries (DPI). The initial assessment included twelve of the Class 3 and 4 noxious weeds declared within Palerang Council area for each of the four major land use types where these weeds had an impact, namely:

1.1.1 Nature conservation
3.2.1 Grazing modified pasture
5.4.2 Rural residential with agriculture
5.4.3 Rural residential without agriculture

For the more widespread weeds, the resulting management category from the weed risk management assessment was often 'manage weed', 'protect priority sites' or 'limited action', depending on the land use type. This then required the identification and mapping of priority sites.

Priority sites

Priority sites for protection against weed invasion were defined as prime agricultural land and nature conservation. Prime agricultural land was already mapped as grazing areas and some key cropping sites.

Nature conservation areas comprised national parks and nature reserves, areas of Endangered Ecological Communities (EEC) and threatened plant sites. EEC mapping was based on regional vegetation maps provided by NSW Office of Environment and Heritage (OEH), with options to improve on their deficiencies currently being explored. Threatened plant sites were also provided by OEH, including via BioNet (OEH 2013), and in discussion with local staff.

After mapping the priority sites buffer areas were then applied to provide a reasonable protection zone. A single buffer distance has been applied across all areas and priority sites to achieve a simple yet effective outcome: 50 m has currently been trialled.

Prioritising inspections

Properties were ranked to determine the schedule for compliance inspections based on the management category(s) for each weed. The exact inspection regime will depend upon available resources and seasonal conditions within the following guidelines:

- Every property to be inspected at least every 5 years;
- Priority sites (including buffers) to be inspected at least every 2 years; and
- ‘Rural-residential with agriculture’ land to be inspected on a revisit schedule of between 2 and 5 years, recognising that while they are not as economically sustainable as larger grazing properties they do include productive land that is of moderate priority to protect.

RESULTS AND DISCUSSION

The project has resulted in a more efficient and consistent approach to scheduling property inspections for compliance with the *Noxious Weeds Act 1993* and for other new weeds. The basic process can be applied quite readily based on the existing NSW Landuse and Threatened species/community maps from OEH, and Weed Risk Management assessments (species templates) for common weeds from DPI. To improve the accuracy of the outcomes, it is recommended that all datasets be reviewed and edited with the benefit of local knowledge.

ACKNOWLEDGMENTS

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ALL EYES FOCUSSED ON HAWKWEED ERADICATION IN THE VICTORIAN ALPS – A PARTNERSHIPS APPROACH

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SUMMARY Hawkweeds are perennial herbs from the Northern Hemisphere, members of the Asteraceae family (daisy) and Hieracium genus. Species from this genus have had severe negative impacts on environmental and agricultural values in both New Zealand and North America. Three species of Hawkweed are known to exist in the Australian Alps, *H. aurantiacum* (Orange Hawkweed), *H. praealtum* (King Devil Hawkweed) and most recently *H. Pilosella* (Mouse Ear Hawkweed). These species have large annual seed production and can reproduce asexually. Hawkweeds are threatening a large area of the High country because of their ability to form monocultures. Areas of land with considerable environmental and agricultural value are impacted. The Victorian Alps Hawkweed Project Control Group (PCG) was formed in 2010 with the aim of eradication of Hawkweeds from the Alps. To achieve this, an alliance was formed between the Department of Environment and Primary Industries, Falls Creek/Mt Buller and Mt Stirling Resort Management, Falls Creek/Mt Buller Ski Lift Companies and Parks Victoria in. Progress towards eradication from 2004 to 2013 is presented, highlighting a successful partnership approach and the importance of our research linkages in working on this issue.

Keywords: Hawkweed, partnership, eradication, surveillance, research.

INTRODUCTION

Hawkweeds (*Hieracium* spp.) are perennial and annual herbs originating from Europe. Hieracium comes from the Greek word 'hierax', meaning hawk. The ancient Greeks reputedly coined the term 'hawkweed' because they thought that hawks ate the sap of these plants to sharpen their eyesight. Four species of hawkweeds have been found naturalised in Australia: orange hawkweed (*Hieracium aurantiacum*), mouse-ear hawkweed (*Hieracium pilosella*), king devil hawkweed (*Hieracium praeltum*) and wall hawkweed (*Hieracium murorum*). *H. murorum* is thought to have been eradicated (Noble 2008).

Hawkweeds are declared noxious weeds in New South Wales, Victoria, Tasmania and Western Australia (McDougall 2004). Hawkweeds are present in two locations within the

Victorian Alps and threaten the ecological viability of twenty four nationally listed flora, one nationally listed fauna species and two nationally listed ecological communities (EPBC Act 1999, Victorian DEPI website). In addition to the alpine infestations, 29 cases of hawkweed have been reported in botanical and residential gardens and at markets in Victoria (Figure 1).

The ability of hawkweed to spread rapidly and detrimentally alter floristic communities has been seen in New Zealand and North America (Duncan *et al*. 1997, Rinella and Shelley 2002, Webb *et al*. 2006). Hawkweeds are regarded as the ‘ideal weed’ species as they have many biological attributes which enhance their dispersal, while they are difficult to detect in an alpine environment. Characteristics such as their rapid growth through vegetative reproduction, high seed output, adaptations for short and long-term dispersal, tolerance to a wide range of environmental conditions and competitive strategies, have allowed this species to become successful invaders in many parts of the world.

Figure 1. Victorian historical overview illustrating the locations of where hawkweeds have been recorded, within Catchment Management Authority regions. Yellow bullets highlight alpine infestations. Currently in New South Wales orange hawkweed is the only hawkweed species recorded and is restricted to a limited area of Kosciusko National Park.

PARTNERSHIP APPROACH TO HAWKWEED ERADICATION

Since 2007, the Department of Environment and Primary Industries (DEPI) and Parks Victoria (PV) have worked in partnership to eradicate hawkweeds from Victoria’s Alps. This partnership has been strengthened through the formation of a multi-organisational Project Control Group (PCG) with representation from Mt Buller and Mt Stirling Resort Management and the Falls Creek and Mt Buller Ski Lift companies. The primary focus of this partnership approach is to direct and coordinate the eradication of hawkweed infestations across the Victorian Alps.

OPERATIONAL OBJECTIVES

To guide the overall management of hawkweed over the next five years, a Victorian Hawkweed Strategy is being developed to provide a framework which sets objectives, performance indicators and trigger points for review of the hawkweed project on a state-wide basis. The overarching operational objectives focus on the delimitation of known infestations, prevention of seed production and dispersal and extirpation (local extinction). For on ground delivery, these objectives are further divided into four components:

(1) on ground works (surveillance, treatment and monitoring);
(2) data management and reporting;
(3) research; and
(4) education and awareness.

These components are conducted simultaneously by agency staff, volunteers, universities and private contractors.

ON GROUND WORKS

Targeted surveillance, treatment and monitoring priorities are guided by DEPI and the PCG and are these are redeveloped each year. The on-ground implementation of these activities in the Alp's are undertaken by partner agencies, while DEPI manages all lowland sites. One of the key challenges has been the annual and longer term costs of monitoring the low percentage of sites that re-emerge for a number of years after its initial detection and treatment.

Chemical trials have been an important step towards improved treatment especially focusing on preventing the re-emergence of treated plants Recent field trials at Falls Creek using Picloram granules have achieved 100% effectiveness following a single application. Although the trial results will take further time to be conclusive, these preliminary findings are extremely encouraging and suggest that the use of granules on specific sites will be an important treatment tool in the future.

A second challenge has been to detect hawkweed in an alpine environment, particularly when plants are in a rosette stage of growth. To further improve detection effectiveness preliminary investigations are being undertaken to assess the feasibility of sniffer dogs for hawkweed discrimination against look-a-like species. If this phase of the trial is successful, the next step will be to assess their detection effectiveness with plants in different phases of their growth cycle in a range of vegetation scenarios (ie. Hawkweed in open grassland verses thickly vegetated shrubs).

DATA MANAGEMENT

For alpine infestations, a hawkweed-specific database has been developed. Each season, detailed site information is captured after confirmed detections are made. In addition, floristic and dispersal information is recorded, which combined with the site information, is used to examine trends, inform surveillance modelling and to monitor progress toward extirpation of each species.

RESEARCH LINKAGES

This program strives for best practice though its research partnerships to solve key issues associated with predicting hawkweed dispersal in the landscape, the detection of sites and evaluating success. Researchers at the University of Melbourne have focussed on hawkweed dispersal by developing models that incorporate predictions on seed dispersal by wind and data on habitat suitability. The model is used to predict where seeds are likely to arrive and successfully germinate through a map of likely occurrence (Williams et al 2008).

To improve hawkweed detection in the landscape, recent field experiments (Moore et al 2011, Hauser, unpublished data; Figure 2) have estimated the relative detectability of different hawkweed species at various growth stages against a variety of background vegetation. These results have been combined with the dispersal results of Williams et al (2008) to provide advice on where surveys should be targeted in the landscape, and how much search effort is required to achieve a desired level of detection confidence (Hauser and McCarthy 2009; Figure 3).

A research linkage with the University of New England and the Australian Centre of Excellence for Risk Analysis (ACERA) is focussed on the development of a spreadsheet tool, known as MoniTool (Hester *et al*. 2013), based on the eradograph concept developed by Panetta and Lawes (2007). Adoption of this tool by biosecurity managers checks the conformity to delimitation (establishing the full spatial extent of the hawkweed incursion) and extirpation (the elimination of individual infestations within this extent) criteria and produces a useful graphical illustration of progress towards achieving each criterion. Data from the hawkweed program has been used with MoniTool to evaluate and update eradication progress of alpine hawkweeds. Eradograph results for orange hawkweed at Falls Creeks (Figure 4) shows good progress towards extirpation and delimitation - each line declines since 2007, following the ideal trajectory.

Figure 2. Field based trial run by the University of Melbourne to investigate detection rates of species in a range of terrain types with plants at different stages of growth and varying levels of surveyor experience. *Photo:* RD Cousens.

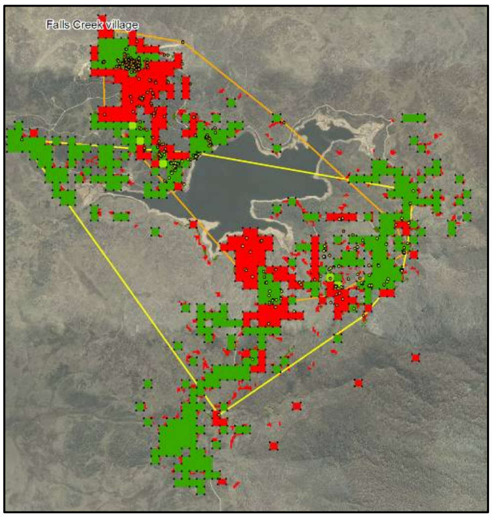

Figure 3. Survey prioritisation for hawkweed used to inform surveillance at Falls Creek. Each individual square represents a 100m x 100m grid. Green grids represent priority areas that predominately have open vegetation; red squares have closed vegetation.

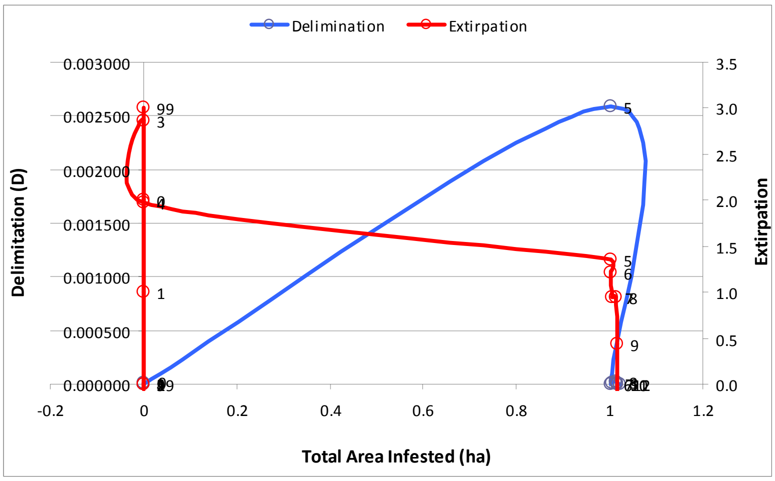

Figure 4. An eradograph showing progress in the extirpation of orange hawkweed, 1998 to 2012 at Falls Creek. Data labels 99-12 represent the years 1999-2012. Progress occurs when both lines head towards the bottom right hand corner; eradication occurs when both converge on the corner.

EDUCATION AND AWARENESS

The community, industry and agencies are important stakeholders in achieving the eradication of hawkweed through their passive surveillance capabilities. For example, bushwalkers frequently walk in remote areas of Victoria's Alp's that are not covered by active surveillance efforts.

In the summer of 2012-13, DEPI staff engaged with Lodge owners at Falls Creek and Mt Buller and Victorian bushwalking clubs to raise hawkweed awareness and to increase passive surveillance capability. Engagement of these groups involved dissemination of identification posters and brochures which are now displayed around the Falls Creek and Mt Buller Villages. Selected stakeholders were also given a short presentation on hawkweed and shown live plants. Engagement focused primarily on detection and reporting of new hawkweed sites. Lodge owners were also encouraged to alert guests to report suspected hawkweed plants.

A large number of volunteers are also recruited each year to participate in active hawkweed over the key flowering period (December to January). Volunteer surveys play a crucial role in the Falls Creek program. In 2012-2013, a total of 66 volunteers surveyed 117 Ha, which is 38% of the total area surveyed. Volunteers discovered hawkweed in six grids.

RESULTS

The trend graph for hawkweed eradication is encouraging. Because of the short seed longevity period of hawkweed, it is possible to meaningfully compare the relationship between the numbers of new infestations detected and progress towards the eradication of known sites on an annual basis. The trend graph (Figure 5) illustrates fewer numbers of hawkweed discoveries found at the Falls Creek and Mt Buller from 2008 onwards, despite continued surveillance, suggesting that the eradication of hawkweed to be technical feasible in these areas.

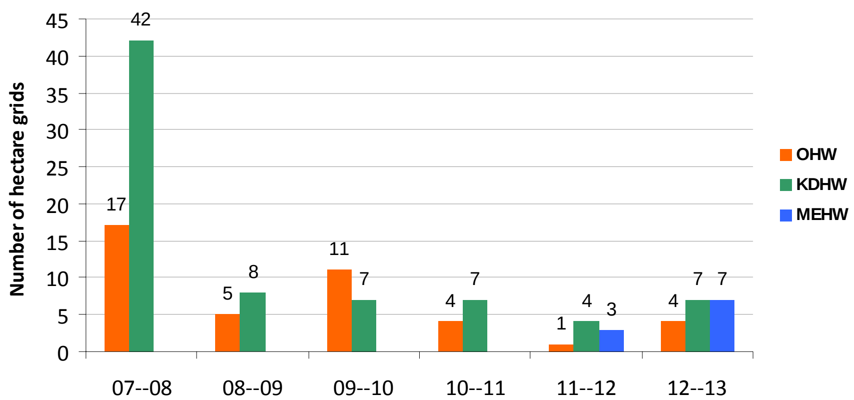

Figure 5. The number of new hawkweed discoveries, counted on a hectare grid, over time in the Victorian Alps. All new grids reported for 2012/2013 were less than 300m from neighbouring infested grids. OHW – orange hawkweed, KDHW – king-devil hawkweed, MEHW – mouse-ear hawkweed. 07-08, refers to the 2007-2008 season.

CONCLUSIONS

In order to eradicate hawkweeds from Victoria, a partnerships approach to direct and coordinate the management of this species is important. The model enables an efficient use of shared resources, improved engagement and the integration of science/research to overcome challenges and guide the development of overarching plans and strategies. The trends are encouraging toward achieving eradication of this highly invasive plant species from the Victorian Alps. Improved treatment methods provide increased confidence that these trends should be strengthened in future years, particularly if the trial investigating the use of sniffer dogs to detect hawkweed prove positive, which have the potential to be part of the answer in overcoming the remaining obstacle, detecting the last hawkweed plant in an alpine environment.

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EASTERN AUSTRALIA BONESEED ERADICATION PROJECT
A state level partnership with local outcomes: eradicating outlier boneseed infestations from Sydney to the Victorian border

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Summary Whilst boneseed *(Chrysanthemoides monilifera* subsp. *monilifera* (L.) Norlindh) has the potential to invade and damage major regions of New South Wales (NSW), it is currently an emerging threat with small outlier populations that are considered eradicable. The Eastern Australia Boneseed Eradication Project is working across southern and western NSW and eastern Victoria to eradicate all known infestations of boneseed and seeks to establish a new national containment line on the NSW border in a strategic, cross-jurisdictional effort. This will protect NSW into the future from the severe impacts of this Weed of National Significance (WoNS).

Keywords: Boneseed, Weed of National Significance, mapping, partnerships, eradication

INTRODUCTION

Alongside its close relative bitou bush (*Chrysthanemoides monilifera subsp. rotundata*), boneseed presents a major threat to the biodiversity of NSW due to its propensity to survive and adapt to nearly every available niche from the ocean to the mountains and from the tablelands to the desert, thereby greatly reducing the abundance and diversity of native flora and fauna across a wide range of habitats. Because of the plant's adaptability and resilience, boneseed can alter natural processes within ecosystems such as changing fire regimes and blocking movement of sand and soil (DEC 2006), thus potentially creating a new set of issues for land managers.

Potential distribution maps created in 2006, revealed that boneseed has the potential to invade most of southern, central and western NSW, however currently only outlier infestations exist in these areas. In response to this threat, NSW regional Noxious Weeds Advisory Groups, including Eastern/Western Riverina and South Coast/Southern Tablelands, have recognised boneseed as an emerging threat and developed management strategies that link with federal and state biosecurity objectives to encourage and enforce the eradication of these outlier infestations (Cherry *et al.* 2011).

Eradication of all outlier boneseed infestations in NSW is essential to prevent further northern and western spread. This will also eliminate any possible adverse impacts from boneseed on biodiversity throughout southern and western NSW, where limited infestations now occur, and in the East Gippsland region of Victoria. Eradication of boneseed in East Gippsland will create a boneseed-free buffer zone between the clean areas in NSW and the core infestations around Melbourne. To the best of our knowledge, boneseed does not occur in the North East region of Victoria, thus by eliminating boneseed from East Gippsland, a natural border consisting of large tracts of remnant forests with very few urbanised areas, will prevent spread into NSW. Additionally, there is a great risk of hybridisation where boneseed overlaps with the range of bitou bush, potentially creating a hybrid plant that has greater invasiveness potential than either sub-species. As such, the eradication of boneseed in eastern

Australia has the added benefit of removing this existing threat of hybridisation at a national level.

Throughout most of NSW, boneseed is now a declared class 2 noxious weed under the *Noxious Weeds Act 1993* (NWA 1993). Under this act, land owners are required to eradicate the plant from their land and keep the land free of the plant. In the East Gippsland Council area, boneseed is a regionally prohibited weed under the *Conservation and Lands Protection Act 1994*. Under this act, land managers are required to take all reasonable steps to eradicate the plant from properties under their jurisdiction.

METHODS

In 2011, members of the project's working party representing Bega Valley Shire Council, East Gippsland Shire Council (VIC), Eurobodalla Shire Council, Shoalhaven City Shire Council, Illawarra District Noxious Weeds Authority, Southern Council's Group, Sutherland Shire Council and Wentworth Shire Council with assistance from the WoNS Boneseed Coordinator, developed a project entitled the Eastern Australia Boneseed Eradication Program. Based on the logic of a biosecurity approach to the eradication of these outlier infestations, the program hopes to ultimately deliver an agreed national boneseed containment line at the NSW / Vic / SA borders. Currently the project partners are locating, mapping and eradicating all outlier infestations to the north of this line.

The project was designed to complement and broaden the scope of work achieved by many land managers in both NSW and eastern Victoria. It was widely recognised that the first step in doing so was to develop a data set that maintained a consistent approach to local data collection across NSW and into eastern Victoria. To create a spatial understanding of all known infestations within NSW, it was decided to map all known infestations by local government area, at suburb and property level scales. To ensure a fine level of detail was being captured whilst not being overly onerous, an attributes table was created that defined a number of parameters such as coordinates, inspector, tenure, number of plants and their reproductive stage (determined by flowering/seeding) and control methods. This information is embedded into a GIS system using points or polygons, depending on the numbers of plants located and their distribution on the property. Whilst field data capture was primarily performed via hand held computers with in built GPS, some project partners opted to record information on hard copy maps, which was then digitised. In the project's first year (2011), the location of all infestations were collected between August and October and then again through the same months in 2012. This allowed for direct comparison of infestations and greatly increased knowledge with regards to the future management of each infestation. All data was collated and analysed in one location, allowing for a well-coordinated cross tenure approach with zero duplication.

The majority of project partners delivered a joint inspection and control program based on enforcement procedures under the NWA 1993 resulting in 100% of located plants being appropriately controlled and mapped. In addition to this approach, Shoalhaven City Council and Illawarra District Noxious Weed Authority also utilised a subsidy funding model that received a 65% uptake throughout residential areas.

RESULTS

The state wide mapping data is based on local property level mapping, which provides an accurate and detailed data set that can be included in state and national maps. This level of detail provides excellent opportunities to learn more about particular infestations and ensure follow up management. Through the project, we have found that given the opportunity, and with access to professional GIS services, all councils, regardless of their internal technological capacity, were able to provide robust local level spatial data.

Suburb level mapping clearly shows boneseed in NSW and East Gippsland is most abundant around urban or peri-urban areas with some isolated infestations in remnant vegetation in the Eurobodalla, Bega and East Gippsland Shire areas (Figure 1). Additionally, suburb level mapping has offered some clues to local nuances in distribution. For example, in the Eurobodalla Shire Council area, it appears that invasion occurs mainly alongside roads and on private properties containing remnant vegetation with a closed or partially closed canopy, and within 2km of a reproductive boneseed infestation. The data collected from this project indicates that, along the south and far south coast of NSW, boneseed seedlings can mature and set seed within 12 months. To date the project has achieved the following outputs (Table 1):

Table 1. Project outputs achieved.

Output	Target	Actual
Boneseed Control	200 ha	1,718.25 ha*
Community Group Engagement	30	30
Indigenous projects	2	2
Indigenous employment	-	13 people (5.8FTE)

*excluding Sutherland, this figure is based on total cadastre controlled

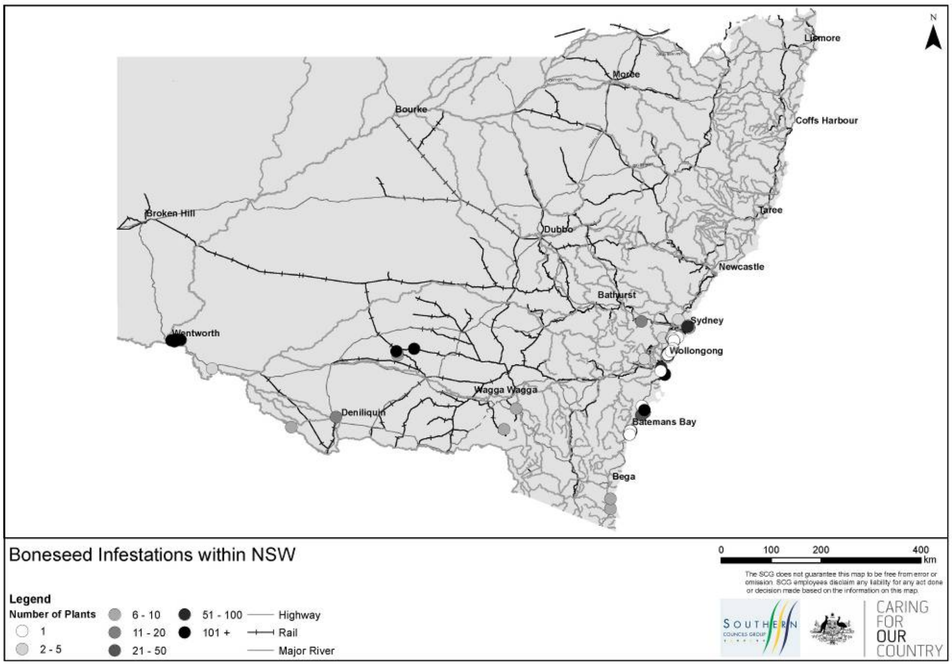

Figure 1. Data collected from the project updates the current data set and additionally displays the number of plants for each infestation at LCA, suburb and property level.

DISCUSSIONS

The multi-jurisdictional model at the heart of the project has ensured a consistent and timely approach to inspections, education programs, control and the collection and sharing of information across multiple land tenure. At the local level, ongoing commitment to the project from all partners will continue to ensure the basic level of resourcing required is upheld until the soil seed bank is extinguished. At the state and federal level, it is important to maintain and increase the scope of this project to ensure the eradication of boneseed moves forward in a coordinated way. To do so will greatly assist with achieving the goal of boneseed eradication for the whole of NSW and East Gippsland.

Maintaining and updating a robust data set will be crucial in eradicating boneseed in NSW as this will allow management of the soil seed bank into the future, while access to centralised data collection and analysis will be vital for information sharing and maintaining the coordination and effectiveness of this program. Further infestations are likely to be found in the project area and vigilance must be maintained. This will be aided by an extension of the project area into the Sydney region. Sydney Weeds Committees are now using the project's methodology and extending the scope of the project throughout the Sydney basin. Together with an existing boneseed eradication project in the Hawkesbury Nepean region, this collaboration now brings all known boneseed infestations in NSW under management. This dramatically enhances the quality of boneseed distribution information and works toward ensuring eradication of all outliers in NSW.

Whilst some of the learnings with regard to boneseed distribution are useful to guide on ground management, further scientific research is required to better understand how vectors of spread affect boneseed distribution patterns, for example movement by foxes, or feeding and roosting sites of birds.

This project reinforces that land managers seeking to use best practice management options as per the Boneseed Management Manual (2006), with the goal of boneseed eradication, must ensure that management is properly resourced and timed annually to prevent seed set and reinfestation of the soil seed bank. The move to a Class 2 Noxious Weed declaration in NSW in 2012 will greatly assist enforcement of eradication, as will the strong partnerships developed through this cross-jurisdictional project.

ACKNOWLEDGMENTS

The achievements of this project were made possible by weeds officers, land managers and regional weeds advisory groups across NSW and Victoria, working in collaboration with the Weeds of National Significance initiative. This work was partially funded through the Australian Government's Caring for our Country.

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WEEDS DOWN UNDER
Invasion of the sub-antarctic wilderness of Macquarie Island[A]

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SUMMARY The sub-Antarctic islands are some of the least inhabited and most protected ecosystems in the world. Due to their isolation and low human visitation they have escaped the worst effects of alien plant invasion. The sub-Antarctic islands are all nature reserves due to their high conservation values, and Australia's Macquarie and Heard Islands are World Heritage Areas. The sub-Antarctic climate is harsh and the vascular flora is relatively species poor, yet they support a number of endemic species. Despite the isolation of these islands, 108 alien plant species have become established since European discovery, posing threats to their biodiversity. *Poa annua* (L.) has quickly become widespread throughout the sub-Antarctic since its introduction and is present on all the major island groups. It is widespread on Macquarie Island, readily colonising disturbed areas and competes with native vegetation for space. The highly invasive capabilities of the grass are due to its high phenotypic and genotypic variability, wide tolerance of environmental conditions, and high fecundity. We are investigating the ecology and control of *P. annua* to broaden understanding of invasion biology and to assist in the development of non-native plant management in the sub-Antarctic and Antarctic region. While previous studies have shown *P. annua* is a successful weed, in this study we will quantify its traits and growth in the sub-Antarctic. This paper provides a background to the study of *P. annua* in the sub-Antarctic.

Keywords: *Poa annua*, alien, weed management, World Heritage, invasive species.

THE SUB-ANTARCTIC

The sub-Antarctic islands are some of the least inhabited and most protected ecosystems on the planet and remain as some of the last true wilderness areas in the world (Whinam *et al*. 2005). Located between 45 and 60 degrees south, they are strongly influenced by the surrounding ocean with the climate characterised by cool, relatively stable temperatures, strong winds and high precipitation (Frenot *et al*. 2005). Due to their remoteness and small land size they are generally species poor, with few families represented, and support few endemic species (Convey *et al.* 2006). Seabirds and marine mammals are abundant, land birds and some insects are present, but indigenous mammalian herbivores are absent, as are trees and shrubs (Chown *et al*. 2001, Convey *et al.* 2006). The unique endemic plants and animals in Sub-Antarctic ecosystems are of considerable conservation value (Chown *et al*. 2001), with Heard and Macquarie Islands listed as World Heritage Areas for this reason (de Villiers *et al*. 2006).

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BIOLOGICAL INVASIONS

Despite their conservation value, the sub-Antarctic Islands are not pristine. The arrival of human beings in the late 18th century brought numerous alien species, with 108 species of non-native vascular plants listed for the sub-Antarctic (Frenot *et al.* 2005), and 284 recorded for the broader Southern Ocean (Shaw *et al*. 2010). They are mainly from common, widely distributed, often weedy families such as Poaceae, Asteraceae, Caryophyllaceae, Brassicaceae and Juncaceae (Convey *et al.* 2006, Shaw *et al*. 2010). While only a few species are naturalised and persistent, some have aggressively invaded native vegetation (Le Roux *et al.* 2013).

Many early introductions were associated with the sealing and whaling industries of the 19th and 20th centuries, although a substantial number of introductions occurred later in the 20th century with scientific and logistic operations (Shaw *et al.* 2010, Le Roux *et al.* 2013). Invasions have not occurred uniformly, with the warmer and more visited islands having more invasive species (Chown *et al*. 1998). The risk of introductions has increased with growing visitation to the islands, however most management plans recognise the threat of non-native species to biodiversity and a range of quarantine procedures have been implemented throughout the sub-Antarctic (Chown *et al.* 2012). Despite this, the number, extent and significance of biological invasions are likely to increase with predicted future climate change and increased human activity (Frenot *et al.* 2005). Biological invasions now pose a serious risk to the Antarctic region (Chown *et al.* 2012) which is evident in the call by the Committee for the Environmental Protection of the Antarctic Treaty System to remove all non-native plants from Antarctica (Committee for Environmental Protection 2011).

POA ANNUA ON MACQUARIE ISLAND

Sub-Antarctic Macquarie Island is listed as a World Heritage Area because of its unique geology and outstanding natural values (Copson and Whinam 2001). The flora is relatively species poor with only 42 species of indigenous vascular plants (Clements *et al.* 2007). Since European discovery, five alien vascular plant species have established on Macquarie Island. Two have been eradicated, but *Poa annua* L., *Cerastium fontanum* Baumg. and *Stelleria media* L. (Vill.) remain (Copson and Whinam 2001).

Poa annua is the most widespread weed in the sub-Antarctic, present on all major island groups (Frenot *et al.* 2005, Convey *et al.* 2006) and also on the Antarctic Peninsula (Molina-Montenegro *et al.* 2012). Frenot *et al.* (2005) and Le Roux *et al.* (2013) classify *P. annua* as an invasive alien as it spreads into native communities and displaces native species. Its ability to withstand heavy grazing has enabled it to spread significantly on islands with introduced herbivores and it infests disturbed areas around settlements, seal wallows, penguin rookeries and glacial moraines (Walton 1975).

It is widespread on Macquarie Island where it colonises disturbed sites, including walking tracks, and competes with native vegetation for space (Copson and Whinam 2001). *Poa annua* increased in response to rabbit grazing and the associated reduction in native vegetation (Bergstrom *et al.* 2009, Scott and Kirkpatrick 2012). However the recent attempt to eradicate rabbits has resulted in another change in vegetation dynamics (Shaw *et al.* 2011) and now more than ever it is critical to understand the distribution and abundance of *P. annua* in this rapidly changing environment. Its current distribution on Macquarie Island is thought be unprecedented (Scott and Kirkpatrick 2012). The observed climatic change of the sub-Antarctic region has also been suggested as a driving factor of its recent spread on Macquarie Island, and more generally for plant invasion across the sub-Antarctic (Scott and Kirkpatrick 2012).

MANAGING *POA ANNUA* ON MACQUARIE ISLAND

Given the widespread distribution of *P. annua* and the high likelihood of its expansion on the Antarctic continent and Heard Island, in this study we aim to investigate the biology, ecology and management of *P. annua* to broaden the understanding of invasion biology and assist in the development of non-native plant management protocols in the sub-Antarctic and Antarctic regions. While previous studies have shown *P. annua* is a successful weed, we will quantify its traits and growth in the sub-Antarctic. A series of *in situ* and *ex situ* experiments will be conducted including studying the response of *P. annua* and native species to manual disturbance, quantifying perenniality in the population, assessing seed longevity and viability and quantifying the soil seed bank. Experiments will also be conducted to evaluate herbicide movement and persistence in sub-Antarctic soils and assess herbicide efficacy and selectivity on *P. annua* and functionally equivalent native species.

Ongoing research will contribute to improving management of non-native species in the sub-Antarctic and Antarctic by investigating how invasive species function and the impact of management techniques, such as physical removal and herbicides, in these high conservation environments.

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DEE WHY CREEK WILDLIFE CORRIDOR PROJECT CONTROL OF WATER PRIMROSE

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SUMMARY Dee Why Wetland is located with the Dee Why Creek corridor and contains one of the last two Warringah remnants of a form of Sydney Freshwater Wetlands known as coastal dune swamp. The non-tidal upper reaches of Dee Why Creek have been modified by residential development, while downstream the system flows through a Wildlife Refuge before discharging into Dee Why Lagoon. Over the years, water primrose *(Ludwigia peruviana)*, a noxious weed introduced from South America, invaded the wetland and covered 75% of the Coastal Dune Swamp. The wetland was also full of numerous species of exotic vines. In 2007, Warringah Council received $57,000 from the Sydney Metropolitan Catchment Management Authority as part of their Green Web Sydney project to control weeds, undertake bush regeneration and restore habitat in the wetland.

Keywords: Habitat restoration, riparian, community engagement, grant projects.

INTRODUCTION

Dee Why Creek is located in Sydney's Northern Beaches approximately 15km from the Sydney CBD. The Dee Why Creek sub-catchment covers an area of approximately 300ha. The non-tidal upper reaches of Dee Why Creek have been modified by residential development, while downstream the system flows through a Wildlife Refuge before discharging into Dee Why Lagoon.

The site area is primarily located in a residential area, though there are some light industrial areas adjacent the riparian boundary in sections. The corridor area includes a diversity of landscape types from bushland and wetlands to parkland and formal sporting fields. There are a number of parcels of land with the corridor which are owned by Council, the Crown and other groups.

Dee Why Wetland is located with the Dee Why Creek corridor and contains one of the last two Warringah remnants of a form of Sydney Freshwater Wetlands known as coastal dune swamp. Over the years, water primrose, a noxious weed introduced from South America, invaded the wetland and covered over 75% of the wetland area. The wetland was also full of numerous species of exotic vines and shrubs including pampas grass (*Cortaderia* species) morning glory (*Ipomoea indica*) Lantana (*Lantana camara*) and blackberry (*Rhubus fruticosus agg.*).

In 2007, Warringah Council received $57,000 from the Sydney Metropolitan Catchment Management Authority as part of their Green Web Sydney project to control weeds, undertake bush regeneration and restore habitat in the wetland, Council matched this funding with $60,000. This project instigated the beginning of a habitat corridor restoration project that is still ongoing today.

METHODS

Stage one of the project saw the engagement of a professional bush regeneration company to undertake weed control and bush regeneration activities. This was done through Council's procurement process resulting in a three year bush regeneration contract with Australian

Bushland Restoration. 'The Dee Why Wetland- Green Web Sydney Restoration Project' began with the following project aims:

- To undertake targeted weed control of noxious and environmental weeds to result in a significant reduction in weeds across the project period.
- To improve the condition of the existing vegetation/ecological communities.
- To maintain and improve habitat for native fauna that use or potentially use the site.

Stage two of the project was to foster involvement of the local community in local natural resource management, through capacity building and awareness raising regarding the project area. On 29 September 2007, the first community planting day was held and a new volunteer bushcare group was established through Warringah's Friend of the Bush program. Over the next three years 500 hours where spent by Friend of the Bush volunteers restoring the edges of the wetland through weed removal and the planting of native tubestock.

In 2009 the Dee Why Wetland volunteer group won the 'Sydney Metropolitan Catchment Management Authority Urban Environmental Project Award'. The group where awarded for an outstanding contribution to improving the natural environment in Sydney.

With the funds received from the Urban Environmental Project Award, the volunteers and Council decided to reclaim an area of unused mown reserve for riparian restoration and corridor extension. During 2008 and 2009, 0.3ha of mown reserve was reclaimed for the protection of the Endangered Ecological Community and important habitat corridor restoration. During this time Warringah Council's community nursery volunteers grew thousands local endemic tube stock for this area.

A 2009 flora and fauna assessment for the Dee Why Valley showed that this area supports one endangered ecological community, over 32 species of birds, two species of frogs and four species of mammals.

Stage three linked South Creek and Dee Why Creek catchments through a shared multi-use path and revegetated habitat corridor funded by Council. During 2011/12, Council invested in constructing the pathway section and rehabilitating 280m of creek line. This work restored approximately 0.9ha of the surrounding riparian area including former industrial land and another small freshwater wetland.

RESULTS

Between the months of July 2007 – June 2010, $120,000 was spent on bush regeneration which has resulted in over 2400 hours on ground, restoring 1.4 ha of the surrounding area. Over 5000 locally grown endemic tube stock was planted along the edge of the wetland. Council's community nursery volunteers collected seeds and assisted with the growing of locally endemic native species for the area.

A major threat to the coastal dune swamp was water primrose, and over 2007-2010 Council invested over $20,000 on the treatment of *Ludwigia peruviana*. This treatment occurred within Dee Why Wetland and the upper reaches of Dee Why Creek. Focus was put into the degraded lower section of the wetland, which contained 95% water primrose. To replace the water primrose (*Ludwigia peruviana*) over 2000 native *Gahnia sieberana* (Gahnia) were planted, which once established began to out compete the water primrose seedlings. The Gahnia also assists with filtration of the creek line and providing important habitat for small animals.

In 2011-2012 new habitat areas where developed along the new multi-use trail on old industrial land and the restoration of natural areas in the upper reaches of Dee Why Creek. The site has been maintained through a mix of grant funding from Sydney Metropolitan Catchment Management Authority and Council.

DISCUSSIONS

The delivery of all the components of this project could not have happened without successful partnerships and the capacity to deliver long term biodiversity conservation outcomes. This project has involved seeking appropriate licensing, addressing multiple threats and prioritising conservation values.

The main focus of this project was to improve riparian bushland condition, wetland health and habitat connectivity through bush regeneration activities and the removal and management of noxious and environmental weeds

Successes have included adequate control of aquatic, vine and shrub weeds and the successful protection of remnant vegetation including the coastal dune swamp community. The continued promotion of areas for Coral Fern colonisation/re-colonisation, good natural regeneration of native species, particularly of Gahnia which replaced water primrose, and adequate growth of plantings has assisted in the recovery of core habitat.

Council will continue with maintenance weeding to ensure progression to the desired native community is achieved. The weedy edge of the remaining uncleared Lantana will be cleared gradually in order to tackle weeds such as turkey rhubarb (*Acetosa sagittata*), blue morning glory (*Ipomoea indica*) and Crofton Weed (*Ageratina adenophora*), and provide critical habitat for small birds.

Creek bank stabilisation through indigenous plantings will also be undertaken over the next few years along unused mown sections of the linked corridor. Community awareness and understanding will be improved through open day and tree planting events including National Tree Day.

Council has applied for a Caring for our Country Grant under the Sustainable Environment Stream to 'improve and maintain urban waterways and coastal environments'. If successful a portion of these funds will be used to remove the concrete half pipe below the wetland and restore the creek banks and riparian areas. This will improve habitats and restore connectivity of fragmented species within the Dee Why Creek Corridor.

ACKNOWLEDGMENTS

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DETERMINING THE EFFICACY OF THE HERBICIDES ENDOTHAL AND DIQUAT ON THE AQUATIC WEED SAGITTARIA IN IRRIGATION CHANNELS[A]

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SUMMARY Sagittaria (*Sagittaria platyphylla* (Engelmann) J.G. Smith) is an emergent aquatic weed that has invaded irrigation systems throughout northern Victoria and southern New South Wales. In earth irrigation channels and drains it impedes water flow, reducing hydraulic capacity and limiting the efficiency of modernised water delivery systems. Currently, there are limited effective control options for sagittaria. This paper describes a field trial to determine the effectiveness of winter applications of the herbicides endothal and diquat in controlling sagittaria, in static irrigation channels. Endothal provided excellent control of both the emergent and submerged forms of sagittaria during winter conditions. Diquat, with and without a gelling agent, was ineffective.

Keywords: *Sagittaria platyphylla*, management.

INTRODUCTION

The growth of aquatic plants in earth irrigation channels and drains impedes water flow, preventing the efficient operation of automated water delivery systems. Sagittaria (*S. platyphylla* (Engelmann) J.G. Smith), is an emergent aquatic weed, native to the United States of America, that has invaded irrigation systems throughout northern Victoria and southern New South Wales (Adair *et al.* 2012). Sagittaria has recently been declared a Weed of National Significance (WoNS) in Australia and additional management approaches are required to reduce its impact.

Currently, control of sagittaria in Victoria is reliant on repeated, high dose applications of the herbicides glyphosate or 2,4-D amine, under off-label permits (Adair *et al.* 2012). These herbicides are applied to above-water foliage rather than the submerged parts of the plant and regrowth is rapid. Acrolein is used for controlling submerged aquatic weeds in irrigation channels but is ineffective on sagittaria (M. Finlay, Goulburn-Murray Water, personal communication).

Screening trials in a shade house have shown sagittaria rosettes (the submerged growth form) are susceptible to the herbicides diquat and two formulations of endothal (endothal dipotassium salt, E-DPS; and endothal mono N,N-dimethylalkylamine salt, E-MAS) (Dugdale *et al.* 2012). One potential option for water authorities to control sagittaria is to treat irrigation channels that hold standing water during the winter irrigation off-season with either of these contact herbicides. This enables a much longer exposure period to be achieved compared to undertaking control during the irrigation season. If diquat and endothal are as effective in the field as in laboratory trials, the use of these herbicides may provide improved control options than those currently available, allowing plants to be treated before

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they become problematic, i.e. large enough to affect hydraulic capacity of irrigation channels and drains. A field trial was therefore conducted to determine the effectiveness of the herbicides, diquat, E-DPS and E-MAS in controlling sagittaria under field conditions during winter. Endothal is not currently registered for aquatic use in Australia.

MATERIALS AND METHODS

A non-flowing irrigation channel was selected near Katunga in northern Victoria that contained abundant sagittaria rosettes and emergent plants. Temporary earth bund walls were constructed at 20 m intervals along the length of a 7 m wide channel, to divide it into 15 separate experimental plots (ponds). The experimental design tested four herbicide treatments and a control, replicated in three blocks of five plots. The herbicide treatments included diquat (Reglone®), diquat + guar gum (Reglone® + Hydrogel®), E-DPS (Cascade®) and E-MAS (Teton®).

On 11 July 2011 herbicide was applied to plots by surface spray. Diquat treatments were applied to achieve a concentration in the water of 1 ppm a.i.; E-DPS and E-MAS were applied to achieve a concentration in the water of 3.6 and 5 ppm a.e. (acid equivalent), respectively (APVMA Permit 9835 rates). Diquat and diquat + guar gum treatments were applied by Hydrogel®-authorised contractors (D.K. and D.A. Cunneen Contractors Pty Ltd). Endothal was applied by Goulburn-Murray Water.

Water quality and herbicide concentrations

Water samples were taken at intervals throughout the trial by combining sub-samples from four locations within each plot. These were used to determine endothal (RaPID Assay® Endothal Test Kit 7007000, Strategic Diagnostics Incorporated) and diquat (ALS Laboratory Group) concentrations and turbidity. Water temperature and depth was recorded at 30-minute intervals within each block using data loggers (HOBO® U20).

Sagittaria biomass

Before treatment and at six weeks (45 days) after treatment (WAT), in each of the 15 plots, all above ground sagittaria biomass from 10 randomly selected quadrats (30 x 30 cm) was harvested and combined. Excess water was removed from the harvested biomass by spinning in a commercial salad spinner until no droplets were produced. Wet biomass was then weighed and a subsample taken and dried to a constant weight (± 0.01 g). The ratio of wet to dry weight for the sub-sample was then used to calculate total dry weight for each sample.

Statistical analysis

The response of sagittaria to herbicide was measured by comparing the biomass for each treatment at each sampling time. Proportional change in biomass between 0 and 6 WAT was calculated as:

Ratio (change in biomass) = biomass 6 WAT / biomass 0 WAT.

where a ratio of 1 represented no change in biomass, a ratio >1 represented an increase in biomass and a ratio <1 represented a decrease in biomass. One sample t-tests were used to test log-transformed biomass ratios. Stata/SE 11 was used for statistical analyses.

RESULTS AND DISCUSSION

Water quality and herbicide concentration

Average water temperature during the trial was 10.1°C (daily average temperature ranged from 6.5 to 13.1°C), which gradually increased with time. Average turbidity in the plots was 196 NTU (Nephelometric Turbidity Units) at the time of herbicide application and remained around 200 NTU until at least 21 days after treatment (DAT). This high level of turbidity is typical of irrigation channels in northern Victoria. Water depth in the plots reduced over the duration of the trial. At the time of treatment average water depth was 0.47 to 0.55 m in all of the plots, as the trial progressed the plots drained at inconsistent rates to be 0.26 to 0.41 m deep, 6 WAT (through a combination of evaporation and percolation).

The actual endothal concentrations were higher than targeted with E-DPS and E-MAS plots averaging 5.9 ± 0.4 and 7.4 ± 0.2 ppm a.e. respectively, 24 hours after treatment. The endothal decay was slow, remaining above 3 ppm a.e. for at least 32 days, resulting in a long exposure period. The average diquat concentration was 0.1 and 0.03 mg a.i. L^{-1} (~ppm a.i.), 1 and 24 hours after application, respectively. This is much less than the target concentration of 1 ppm a.i.

Sagittaria biomass

Prior to any chemical application, there was a mixture of both emergent and submerged (rosette) growth forms of sagittaria along the length of the channel. Most of the emergent plants were old and fibrous with some grazing and frost damage evident; rosettes were also large with old leaves present.

Both formulations of endothal provided excellent control of above ground sagittaria biomass (emergent plants and submerged rosettes). There was evidence of herbicide injury to sagittaria by both endothal formulations (E-DPS and E-MAS) within eight days after treatment, observed as blackening and decaying leaves. By 6 WAT, E-DPS reduced biomass on average by 97%, while E-MAS reduced biomass by 92%, relative to pre-treatment biomass (Table 1). These reductions in biomass were significant (P<0.05; Table 1). The remaining plant material consisted of crowns of large adult plants, which remained intact, but they were only a few cm tall with no leaf material present.

Table 1. Effect of herbicide on sagittaria biomass and a comparison of biomass ratios at 0 and 6 weeks after treatment (WAT). The P-values and confidence intervals were obtained from t-tests of the difference between log-transformed ratios. The ratio (change in biomass) = biomass 6 WAT / biomass 0 WAT): a ratio >1 represented an increase in biomass and a ratio <1 represented a decrease in biomass ± the standard deviation (sd).

Herbicide Treatment[1]	Mean biomass 0 WAT ± sd (kg m^{-2})	Mean biomass 6 WAT ± sd (kg m^{-2})	% change in biomass	Mean ratio ± sd	P-value	95% confidence intervals
None	3.3 ± 2.2	5.0 ± 2.7	75.1	1.75 ± 1.00	0.283	0.41–6.11
E-DPS	2.6 ± 1.4	0.1 ± 0.2	-96.7	0.03 ± 0.04	0.026	0.002–0.32
E-MAS	3.4 ± 2.2	0.2 ± 0.2	-92.1	0.08 ± 0.08	0.040	0.004–0.71
Diquat	2.6 ± 1.9	3.0 ± 3.0	7.5	1.08 ± 0.42	0.978	0.32–3.19
Diquat + guar gum	3.0 ± 2.3	3.9 ± 2.6	38.3	1.38 ± 0.15	0.040	1.04–1.83

[1]Abbreviations: E-DPS = endothal dipotassium salt; E-MAS = endothal mono N,N-dimethylalkylamine salt; sd = standard deviation; WAT = weeks after herbicide treatment.

Diquat was not effective on sagittaria. Some necrosis was evident from the diquat treated plots by 2 WAT, but this was not apparent at 6 WAT where there was no significant plant damage. Biomass in plots treated with diquat had increased at 6 WAT compared to pre-treatment biomass (Table 1).

The efficacy of herbicides on aquatic weeds is driven by the relationship between herbicide concentration and exposure time (CET): longer exposure times, higher herbicide concentrations or both, result in greater control (Netherland 2009). In this trial endothal provided excellent control of sagittaria. The herbicide was applied at high concentrations and it persisted in the plots for the full six weeks of the trial. The long exposure time was achieved due to static water conditions and because endothal activity is sustained in winter conditions (because microbial activity, which is the primary mode of decay, is slowed in cool conditions (Reinert *et al*. 1986).

Although good control was achieved with diquat in a shade house trial (Dugdale *et al.* 2012), this was not replicated in this field trial and there are two likely reasons for this. Firstly, the plants in the shade house trial were young submerged rosettes while the field trial consisted of old fibrous plants (rosette and emergent forms). Secondly, the field plants were exposed to diquat for a very short period (diquat was only 10% of the target concentration 1 DAT), almost certainly caused by de-activation of the diquat cation due to suspended sediments in the water column, associated with high turbidity in the field trial (Bowmer 1982, Hofstra *et al.* 2001). It was postulated that the addition of the gelling agent (guar gum) may interrupt the de-activation process but there was no evidence of an increase in efficacy to support this.

The current field screening trial has shown:

1) effective control of sagittaria can be achieved with winter application of endothal to non-flowing water during the winter irrigation off-season;
2) both formulations of endothal (E-DPS and E-MAS) are very effective against sagittaria adults (emergent plants) and rosettes (submerged plants);
3) endothal activity is sustained when applied to static water in winter: it persisted for at least 6 WAT in this trial and
4) diquat is ineffective in turbid irrigation channels at reducing sagittaria biomass, with and without a gelling agent, during winter conditions.

This study has demonstrated that it is possible to control sagittaria with endothal during winter in static irrigation channels. In order to progress registration of endothal in Australia, further research is needed to determine the CET relationship for endothal and sagittaria in the field. Further trials conducted in irrigation channels in Victoria and NSW will determine if endothal presents as a useful control option for sagittaria.

ACKNOWLEDGEMENTS

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HOW TO TAME YOUR ALLIGATOR

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SUMMARY Alligator Weed is a native to South America which has become wide spread in tropical and warm temperate regions of the world. It was introduced into Australia over 70 years ago, since this time it has spread into several catchments along the New South Wales coasts and west into the Riverina, Gunnedah, Tamworth and the Mudgee areas. It is also found in Queensland and Victoria. It is considered to pose one of the greatest threats to waterways, wetlands, floodplains and irrigation systems in Australia. It can quickly spread in aquatic areas choking rivers, streams and drainage canals, and can easily be spread by vegetative means with the flow of water or machinery working in aquatic areas. It also grows in terrestrial locations where it can be spread by machinery or the movement of animals. It causes a major problem to cropping and irrigation enterprises and can cause photosensitivity and liver damage in animals that graze on it.

It is an extremely competitive plant which produces extensive underground root systems that can grow more than a metre deep in some soils. Alligator Weed was first identified in the Shoalhaven City Local Government area in 2010, growing in a dam on a property in the Berry Mountain area, which is north of Nowra. This paper outlines the success of a partnership arrangement between the land owner, Shoalhaven City Council, Southern Rivers CMA and the Department of Primary Industries in developing a plan to control this infestation and obtain a Caring for Country grant to carry out the control work.

Keywords: Alligator Weed, Weed of National Significance, Shoalhaven City, Southern Rivers CMA, Caring for Country, partnerships

INTRODUCTION

Alligator Weed *Alternantheria philoxeroides*, is a native of South America which has become wide spread in tropical and warm temperate regions of the world. It is present in the United States, Argentina, Caribbean Islands, parts of Africa, India, Malaysia, South East Asia, Indonesia and New Zealand; so it is a wide spread world traveller. It is considered to be the one of the greatest threats to waterways, wetlands, floodplains and irrigation areas in Australia. It can infest crops and pastures, chokes dams and water courses and causes photosensitivity and liver damage in livestock.

It was first recorded in Australia in Newcastle in the 1940s, where it was found growing on ballast dumped by war time shipping in this port. Since this time it has spread extensively through the Hunter Region of New South Wales and has found its way into the Hawkesbury Nepean River systems, Riverina, Northern Rivers and has finally visited the Shoalhaven, occurring in a farm dam on Berry Mountain, north of Nowra.

Its most prominent characteristics are white, Clover like flowers, its bright green dense foliage and its hollow stems, this feature sets it apart from other plants such as Senegal Tea, Hygrophila, Ludwigia and some of the joyweeds.

Alligator Weed does not have spikes or thorns; does not produce seed; is not poisonous, in fact some members of the Sri Lankan community use it as a cooking herb. It does not even have teeth to bite you like its namesake; so why is it such a problem; the answer is. It is almost impossible to completely control with herbicides, currently available. It infests terrestrial as well as aquatic locations, where its roots can extend down, well over a metre. Repeated applications of herbicide using Glyphosate or Metsulfuron products tends to burn off the above ground parts of the plant, but due to a unique feature the herbicide is not translocated to the full depths of the root system which can then reproduce new plants.

METHOD OF SPREAD

Alligator Weed does not produce seed, so all reproduction is by vegetative means. The plant is readily spread by movement of water, earthmoving machinery used to clean out drains and dams, slashers and other farm machinery, boats and trailers, perhaps water birds and animals drinking and grazing, in infestations, particularly where the soil is boggy. It was even thought a possibility that the Rural Fire Service in our area may have inadvertently spread Alligator Weed during drafting and pumping exercises with their fire tanker.

Out of all these methods of spread, the most effective is by the movement of water in rivers and streams, once detected, both upstream and downstream of the infestation must be checked, before attempting to formulate a control plan.

In the case of the infestation in Shoalhaven, a survey of the upstream catchment proved negative; however, a survey of the downstream side of the dam wall did reveal some plants. The terrain further downstream is extremely difficult and will require ongoing monitoring very closely to check for infestations.

FIRST INFESTATION IN SHOALHAVEN

The owner of the property first contacted the Council and asked to identify a plant that was growing prolifically in his dam for some time. The plant was identified as Alligator Weed and NSW DPI was contacted and then assisted with an inspection of the site and discussed control options and potential costs

The property owner was alarmed at some of the cost estimates to carry out excavation and control on his land. At this time the CMA was asked to become involved and applied for a Caring for Country grant through the Southern Rivers CMA to carry out the recommended control practice of excavating the area and burying the material.

DEVELOPING THE GRANT APPLICATION

NSW DPI suggested that there was an opportunity to apply for project funding through the Australian Government's Caring for our Country program. It was decided very early on to take a broad approach to managing aquatic weeds in the region as they were becoming established in several shires. It was thought that the Caring for our Country team would look more favourably on the application if it included several project partners from throughout the region rather than on only one site. This broad approach required management across several jurisdictions so it made sense for Southern Rivers CMA to manage the project.

Another reason for CMA managing the project is that it required landholders to agree to ten year management plans for their site. The landholders are required to manage the infestation after the initial investment in weed management on their property. This management is reported on annually.

In early September 2011 Australian Government notified the CMA that the grant application for $71,500 was successful. It took about ten months from the initial identification of Alligator weed on Berry Mountain to having the full amount of funds available to manage the project.

TENDERING FOR SERVICE

Three quotes were requested for the project works. A tender brief was developed with the scope of works being:

- Remove vegetation from the dam including sediment to a depth of not less than 100mm.
- Vegetation shall be placed on plastic liner, in the paddock adjacent to the dam. This material will then be covered with plastic and left to dry out to reduce its volume.
- Bury all vegetative material on site, in a pit to be dug next to the spoil site, to a minimum depth of 6 feet.
- The pit for burial shall be lined with clay and then plastic lined.
- Appropriate safety fencing to be erected around the pit
- All disturbed areas will be sown with grass seed and fertilised upon completion.
- Appropriate biosecurity controls will be implemented to ensure that the Alligator weed cannot spread from the site. This includes the erection of sediment fences and thorough wash down of all plant and vehicles prior to leaving the site.

The quotes that were received for the service were up to $97,000 plus GST. However the project managed to get the job done for a little under $60,000.

IMPLEMENTING THE PROGRAM OF WORKS

Shoalhaven City Council reduced the density of the weed by spraying with metsulfuron-methyl several times since it was discovered in December 2010. The project earth works commenced in November of 2012 and took about five weeks to complete. The first step was to pump the 1½ hectare dam dry prior to putting machinery into it. Water was passed through a large purpose built filter to ensure that no pieces of Alligator weed would be washed further into the catchment. The filter was also bunded so that fragments could not enter other parts of the environment. The contractor made the decision to start cleaning the upstream portion of the dam before all of the water was removed.

A 20 tonne excavator was brought on site and dug a pit 20m x 10m x 4m deep which was lined with builders plastic. The excavator then started to clear out the dam and the spoil was transferred to the pit with a very large dump truck. The pit filled up much more quickly than anticipated, so once it was full the excavator was washed down, to eliminate the possibility of contamination of topsoil, and then dug a second pit the same size. This again was filled up reasonably quickly but it was big enough.

It was at this point that the mid section of the dam finally dried up properly only to reveal a large patch of alligator weed that had been missed. It was quickly decided that a third pit would need to be dug to accommodate the remaining spoil. This one was only 5 x 5m but another day was spent on the project that might not have been needed if the dam was completely dry as planned.

All machinery was washed down on site and checked thoroughly prior to leaving the site. The machinery was washed down again at the contractor's depot to ensure that alligator weed would not spread onto their next job. After the machinery had left the site all areas that may have come into contact with alligator weed was sprayed with metsulfuron-methyl. The very last thing undertaken was to seed the project site with grasses.

As part of the broader project two Recognising Water Weeds workshops were held in the local area for landholders. The workshops were delivered by DPI's Aquatic Weeds project officer, with a total of 25 participants attending.

PROJECT OUTCOMES

- A total of 800m³ of spoil was removed from the dam and buried.
- 130 hectares of downstream riparian land has hopefully been protected from being infested with Alligator weed. This estimation is only for the lower Brogers Creek catchment and does not include downstream where it enters the Kangaroo River and the Sydney Catchment managed areas.
- Skills and knowledge of 25 landholders about aquatic weeds improved.

CHALLENGES AND IMPROVEMENT

The biggest challenge for this project was the weather. Shortly after we received the project funding we had two of the wettest summers in recent memory. Even with the long dry period through last winter the ground was still very soft. The project had to wait until well into the spring before the works program could be implemented without getting machinery stuck.

The dam should have been completely dry prior to works commencing. This would have eliminated the need for a third pit to be dug. The contractor made the decision to start cleaning the dam without consultation. Estimating the amount of spoil to be removed from the dam was much more difficult than initially envisaged. More than double the estimate was removed because it was underestimated how deep the roots went into the mud and no one knew exactly how deep the dam was. Even if we had allowed for 50% more spoil we still would have been short on the estimate.

Communication about the importance of biosecurity on site was very challenging. Briefing the contractor about the importance of not spreading the weed further by fragments in mud was more difficult than it should have been. At the initial site induction all staff were told how to contain the weed. However a week into the project the contractor's staff changed and the contractor did not brief the new team as well as we would have liked. The issue was resolved but some extra cleanup work was required which costs money. The agreement with the contractor should have contained a clause about all of their staff having to be briefed by Southern Rivers CMA prior to commencing work on the site.

The project site has responded extremely well. There is a very small patch of regrowth in one corner, but it is manageable particularly as we are now in a cooler period. This will be dug out by hand and taken to a council facility for disposal. The project team believe that alligator weed is on its way from being eradicated from the site.

ACKNOWLEDGEMENTS

The success of this project is due to a cooperative partnership of officers from Shoalhaven City Council, Southern Rivers CMA, NSW DPI and the property owner.

Funding for the project was sourced from NSW DPI, Shoalhaven City Council and an Australian Government, Caring for Country grant.

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RECENT ADVANCES IN GALENIA CONTROL[A]

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SUMMARY The options available to control galenia (*Galenia pubescens* (Eckl. & Zeyh.) Druce) in Australia are restricted to two herbicide treatments and physical removal. This may limit the success of control options in limited situations. Furthermore, regular control with few herbicides may result in herbicide resistant populations. A total of six experiments were conducted to investigate the potential herbicide treatments for galenia control. Many new herbicide treatments were considered worthy of obtaining label registrations or off-label permits via the Australian regulator, the Australian Pesticides and Veterinary Medicines Authority (APVMA). These treatments should allow effective control, with less off-target impacts and under more situations than currently registered. At least five different mode-of-action herbicides were effective on galenia; enabling herbicide group rotation, a strategy that will delay the onset of herbicide resistance.

Keywords: *Galenia pubescens*, herbicides, registration, noxious weed, resistance.

INTRODUCTION

Galenia pubescens (Eckl. & Zeyh.) Druce (galenia) was first reported in Australia in the early 1900's in Victoria (AVH 2013). It is reported to be in many southern states of Australia (Prescott and Venning 1984). For the past 30 years, galenia infestations in the Upper Hunter region of New South Wales have been getting more severe. Galenia is a perennial native of South Africa (Arnold and De Wet 1993) and has become prolific in the prolonged warmer conditions. It forms a roughly circular mat on the ground, growing out from a central stem, very similar in habit to wire weed (*Polygonum aviculare* L.), except that galenia has substantial, thick, vertical layering. It is often found in mine reclamation sites, roadsides, fence-lines, pastures, wasteland, lawns and bushland. Although not classed as a noxious weed in the Upper Hunter, it is deemed a Class 4 weed in the Tamworth Regional and Liverpool Plains Shire Council regions.

Previous research findings on chemical control are very limited. McMillan and Strachan (1986) and McMillan and Cook (1989) investigated various potential herbicides and found some effectiveness from 2,4-D, picloram and glyphosate based products along with tebuthiuron. Biological control of this weed does not exist in Australia. Furthermore, only two products are registered for its control (APVMA 2013). These herbicides are picloram + triclopyr (Grazon® DS) and its derivative picloram + triclopyr + aminopyralid (Grazon® Extra). This treatment is associated with some off-target injury to native trees and shrubs, especially in mine reclamation sites. In addition, this treatment is not suitable for situations in the Hunter region such as cropping (lucerne, maize, oats etc.) and roadsides.

This paper presents experimental results aimed at developing new treatments for the control of this weed. An experiment specifically aimed at reducing off-target damage to native sapling tree and shrub species will be discussed.

The data from this report will be used to support a minor use pesticide permit via the Australian Pesticides Veterinary Medicines Authority, allowing better choice of herbicides in

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New South Wales and much less off-target damage. With the granting of a new pesticide permit, effective and safer management of galenia will be achieved at a much reduced cost compared to standard practice.

MATERIALS AND METHODS

All the experiments were conducted in the Upper Hunter region. Application of blanket-applied herbicides was via a hand-held battery powered boom-spray applying a water volume of 100 L ha^{-1} through 110-01 Lowdrift™ nozzles at 300 kPa. Spot spray treatments were applied with a 5 L portable knapsack using a variable cone nozzle applying a water rate of 1000 L ha^{-1}. Unless otherwise stated, all herbicides were applied to actively growing galenia at the flowering to early fruit growth stage. All herbicide treatments are listed in the results tables or figures specific to each experiment.

Experiment 1. Evaluation of a range of herbicides

This experiment investigated a range of herbicides in a grass dominated reserve. The blanket-applied treatments were sprayed on 28 October 2008 at Aberdeen, New South Wales. At the time of application, the dry bulb temperature was 33°C and humidity was 19%. The plot size was 3 metres by 3 metres with a 50 to 90% ground cover of galenia. Some moderate moisture stress in plants was noted at the time of spraying.

Experiment 2. Evaluation of the additive effects of herbicide mixtures

Herbicides containing aminopyralid were compared with similar products not containing aminopyralid, to determine the additive effects of this active ingredient. The blanket-applied treatments were sprayed on 16 February 2010 at Singleton, New South Wales. At the time of application, the dry bulb temperature was 28°C and humidity was 55%. The plot size was 4 metres by 5 metres with a 80 to 100% ground cover of galenia.

Experiment 3. Seasonal impact on herbicide efficacy

Three effective herbicides were sprayed in three separate seasons to determine seasonal effects. This experiment was located adjacent to Experiment 1. The blanket applied treatments were sprayed on 27 October 2008, 3 March 2009 and 28 April 2009 at Aberdeen, New South Wales. The basic weather conditions on 27 October 2008 at the time of application were: dry bulb temperature 30°C and humidity 27%. For 3 March 2009 and 28 April 2009 the temperature was 31°C and 21°C, respectively, and the relative humidity was 35% and 40%, respectively. The plot size was 3 metres by 3 metres with a 50 to 90% ground cover of galenia. A moderate degree of moisture stress in plants was noted on 27 October 2008.

Experiment 4. Herbicide rate responses

Seven herbicides were applied at four application rates in a grass dominated pasture. The blanket-applied treatments were sprayed on 23 December 2008 at Aberdeen, New South Wales. At the time of application, the dry bulb temperature was 28°C and humidity was 47%. The plot size was 2 metres by 5 metres with a 20 to 70% ground cover of galenia.

Experiment 5. Evaluation of a "double-knock" on galenia

This experiment was designed to investigate the effects of double-knocking: the use of two successive but different herbicide treatments on galenia. Firstly, systemic herbicides were applied on 25 November 2008, followed 16 days later by a desiccant herbicide on 10 December 2008. This experimental site was located on a neglected wasteland at Aberdeen, New South Wales. The temperatures at the times of application were 27°C and 32°C, respectively, whilst humidity was 39% and 32%, respectively. The plot size was 4 metres by 5 metres with a 50 to 100% ground cover of galenia.

Experiment 6. Evaluation of spot spraying on galenia

A range of herbicides were applied as spot treatments. The treatments were sprayed on 26 February 2010 at Singleton, New South Wales. At the time of application, the dry bulb temperature was 27°C and humidity was 73%. The plot size was 10 metres by 5 metres with a 20 to 50% ground cover of galenia. Both Experiments 5 and 6 were located on mining reclamation areas.

Measurements and statistics

A subjective and non-destructive control rating score was used to assess galenia control. Scores range from zero (nil control) to five (complete kill) with a score of three indicating commercially acceptable control (80% biomass reduction) and four excellent control (95% biomass reduction).

All experiments used a random complete block design with three replicates. Analysis of variance was completed on data using Genstat Version 5.1. Differences between treatment means were determined using a Least Significant Differences statistic at the 5% level of confidence ($P<0.05$).

RESULTS

Experiment 1. Evaluation of a range of herbicides

The time required to obtain commercially acceptable control of galenia depends on the herbicide used (Table 1). Grazon® Extra treatments (2.5 and 5 L ha^{-1}) were the superior treatments when assessed 183 days after treatment (DAT). Control improved with these treatments at each assessment time with commercially acceptable control achieved 36 DAT. There is scope to reduce the Grazon® Extra rates below 2.5 L ha^{-1} as the label registered rate of 5 L ha^{-1} appears excessive.

Herbicides such as metsulfuron (80 g ha^{-1}), Esteron® LV (2.2 L ha^{-1}), Hotshot® (4.7 L ha^{-1} aminopyralid + fluroxypyr) and Tordon® 75-D (4 L ha^{-1} piclorma + 2,4-D amine) achieved >80% control 183 DAT, all steadily improving control over time. Paraquat treatments were associated with high initial control scores (brown out) followed by lower scores in later assessments due to the regrowth. Addition of atrazine to paraquat improved and prolonged the level of control. Esteron® (2,4-D in the lower volatile ester form) was more effective than the amine formulation of 2,4-D (Amicide® 625). Glyphosate did not work satisfactory in this experiment and may have been hindered by seasonal effects, which were investigated in Experiment 3 below.

Table 1. Herbicide control efficacy on galenia (visual control score 0 = no control, 3 = commercial control and 5 = total control). Control scores were assessed at various days after treatment (DAT). All herbicides had Uptake® added at 0.5% v/v (500 mL 100 L^{-1} water).

Herbicide	Product rate ha^{-1}	Control score 9 DAT	Control score 36 DAT	Control score 77 DAT	Control score 183 DAT
Untreated control	-----	0.2	0.0	1.0	0.5
Grazon® Extra	2.5 L	2.2	2.9	4.5	5.0
Grazon® Extra	5 L	2.6	3.5	4.8	4.9
Glyphosate (450 g L^{-1})	2 L	0.7	1.8	1.2	0.0
Glyphosate (450 g L^{-1})	4 L	1.6	2.5	1.3	1.1
Tordon® 75-D	2 L	1.4	2.3	2.9	2.9
Tordon® 75-D	4 L	1.8	2.5	2.9	4.3
Esteron® LV (2,4-D ester 680 g L^{-1})	2.2 L	2.0	2.6	3.2	3.8
Amicide® 625 (2,4-D amine 625 g L^{-1})	2.4 L	1.9	2.0	1.6	1.3
Broadside®	5 L	2.7	2.7	2.2	1.2
Metsulfuron (600 g kg^{-1})	80 g	1.1	2.8	3.3	3.8
Paraquat (250 g L^{-1})	2.4 L	4.3	3.1	2.5	0.6
Bromoxynil (200 g L^{-1})	2.8 L	2.8	1.4	1.8	0.3
Starane® Advanced	2 L	1.6	1.2	1.7	0.3
Hotshot®	4.7 L	2.3	2.3	2.4	3.1
Igran® + Esteron®	1.5 L + 2.2 L	3.6	3.9	3.9	3.2
Atrazine (500 g L^{-1})	3 L	1.8	3.2	2.1	0.7
Atrazine (500 g L^{-1}) + paraquat (250 g L^{-1})	3 L + 2.4 L	4.3	4.4	3.3	2.0
LSD ($P<0.05$)		0.4	0.6	0.5	0.8

Experiment 2. Evaluation of the additive effects of herbicide mixtures

The aim of this experiment was to determine if aminopyralid improved control of galenia by comparing Grazon® Extra (triclopyr, picloram and aminopyralid) with Grazon® DS (triclopyr and picloram) and Hotshot® (fluroxypyr and aminopyralid) with Starane® Advanced (fluroxypyr). These comparable products were applied so that the other active ingredient rates in the product were identical (Table 2).

The data showed that aminopyralid greatly improved the control of galenia (Table 2). This is particularly the case when comparing the levels of control between Starane® Advanced and Hotshot® at comparable rates of fluroxypyr; the only exception being the control scores at 43 DAT (Table 2). Aminopyralid notably improved the efficacy of Grazon® Extra, but only at the 400 mL ha^{-1} rate (Table 2). It appears the picloram component of Grazon® Extra is greatly contributing to galenia control and aminopyralid is assisting with improved control at the commercially effective rates when compared to the herbicide treatments containing fluroxypyr.

Grazon® Extra and its related product Grazon® DS were very effective at rates much lower than the registered rate of 5 L ha^{-1}. In this case it appears rates as low at 800 mL to 1.2 L ha^{-1} seem adequate. This information will be crucial to obtain new recommendations to allow the use of lower rates of Grazon®, thus reducing the amount of residual active ingredients in the soil, lowering the damage risk to young native trees and shrubs and reducing applied herbicide costs.

Table 2. The effects of aminopyralid in formulations of herbicides on galenia. Control scores were assessed at 43 and 120 days after treatment (DAT). All treatments had Uptake® added at 0.5% v/v (500 mL 100 L^{-1} of water).

Herbicide	Product rate per ha	Control score 43 DAT	Control score 120 DAT	% biomass reduction 120 DAT	% biomass reduction 233 DAT
Grazon® DS	400 mL	2.6	2.5	62	57
Grazon® DS	800 mL	2.2	3.5	87	93
Grazon® DS	1.2 L	3.1	4.3	96	97
Grazon® Extra	400 mL	3.5	2.7	73	82
Grazon® Extra	800 mL	2.6	3.7	87	97
Grazon® Extra	1.2 L	1.6	4.6	98	100
Starane® Advanced	525 mL	3.3	1.2	15	8
Starane® Advanced	1.05 L	3.7	1.3	18	5
Starane® Advanced	1.58 L	1.9	1.5	20	12
Hotshot®	1.25 L	2.9	2.4	55	35
Hotshot®	2.5 L	2.3	2.6	62	68
Hotshot®	3.75 L	1.5	3.2	81	91

Experiment 3. Seasonal impact on herbicide efficacy
Glyphosate was not effective at the spring application time but was moderately effective in early and mid autumn (Figure 1). This spring application compares with the glyphosate application in Experiment 1, with both considered commercially unacceptable. The poor efficacy for application in spring was confounded by early signs of moisture stress. This 'timing' effect needs to be re-investigated without the secondary effects of moisture stress.

Seasonal application effects or moisture stress did not seem to be important for Grazon® Extra and Tordon® 75-D. However, there seemed to be a slight drop in control for the spring applied Tordon® 75-D (Figure 1).

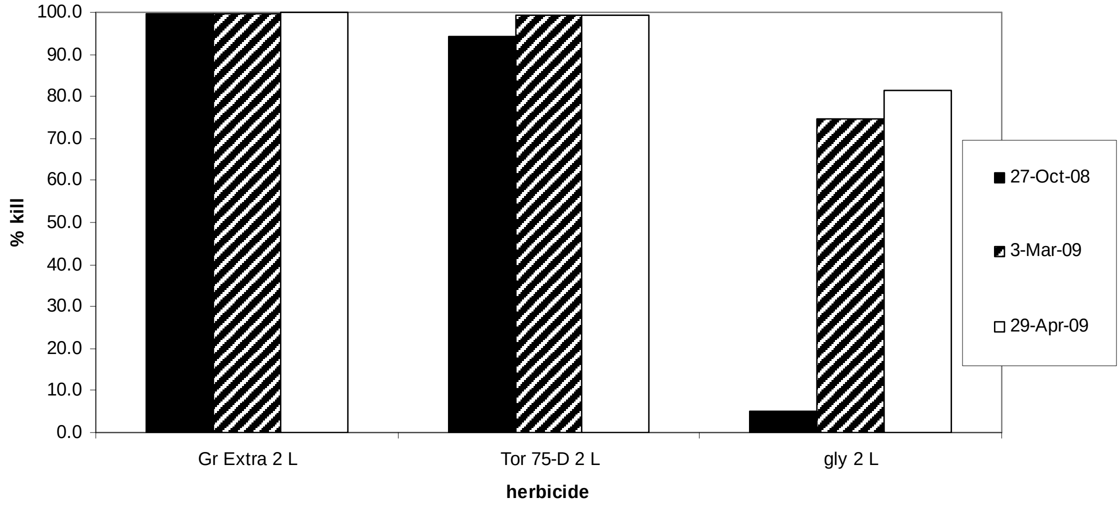

Figure 1. Seasonal effects of three effective herbicides on galenia (assessments made 553 days after treatment (DAT)). The herbicides applied are abbreviated as follows: Gr Extra = Grazon® Extra at 2 L ha^{-1}; Tor 75-D = Tordon® 75-D at 2 L ha^{-1}; and gly = glyphosate (450 g L^{-1}) at 2 L ha^{-1}).

Experiment 4. Herbicide rate responses

Herbicides that maintained a galenia control rating consistently above 4 (excellent control) for all rates tested were Grazon® Extra, Tordon® 75-D, atrazine and Igran® (Figure 2). The amine formulation of 2,4-D was used in this experiment and excellent control was achieved at rates greater than 3 L ha^{-1}. Metsulfuron gave best control at 40 and 60 g ha^{-1} but at the 80 g ha^{-1} rate control was reduced. Most rates of glyphosate (450 g L^{-1}) 2 to 6 L ha^{-1} controlled galenia inadequately, below commercial standards, except for the highest rate (8 L ha^{-1}) which nearly controlled all plants.

The excellent control achieved by atrazine and Igran® (terbutryn) is associated with increased activity and availability of these herbicides on sandy soil, which was present in this experiment.

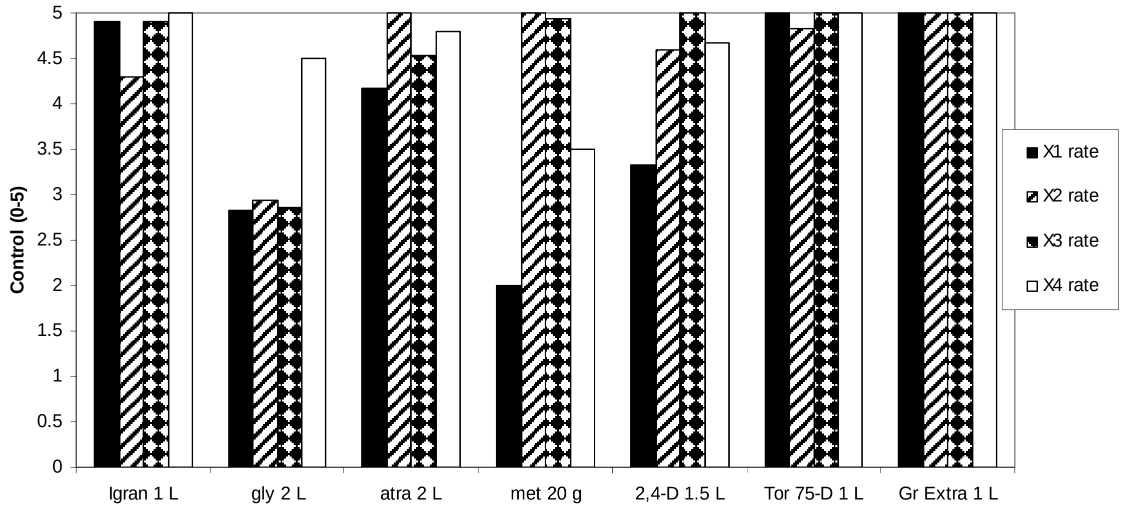

Figure 2. The rate response of seven effective herbicides on galenia (assessments made 315 days after treatment DAT). The herbicides applied were as follows: Igran® = terbutryn (500 g L^{-1}); gly = glyphosate (450 g L^{-1}); atra = atrazine (500 g L^{-1}); met = metsulfuron (600 g kg^{-1}); 2,4-D = 2,4-D amine (625 g L^{-1}); Tor 75-D = Tordon® 75-D (1 L ha^{-1}); and Gr Extra = Grazon® Extra (1 L ha^{-1}). Product rates indicated on the x axis are the X1 rate per hectare. The X2, X3 and X4 were 2, 3 and 4 times of the X1 rate, respectively).

Experiment 5. Impact of a "double-knock"
Double knocking is a technique developed in the cropping regions of Australia whereby a systemic herbicide is applied as the first "knock" and followed up with desiccant herbicide such as paraquat as the second "knock". In order of most effective to least effective, the first "knock" herbicides were, Grazon® Extra, Tordon® 75-D, 2,4-D amine, atrazine, glyphosate, Igran® (terbutyrn) and metsulfuron (Figure 3). While atrazine and Igran® (terbutyrn) were considered effective in the rate response experiment, they were ineffective in this experiment, possible due to the heavier soil type at this location. Glyphosate and metsulfuron were also well below commercial acceptability.

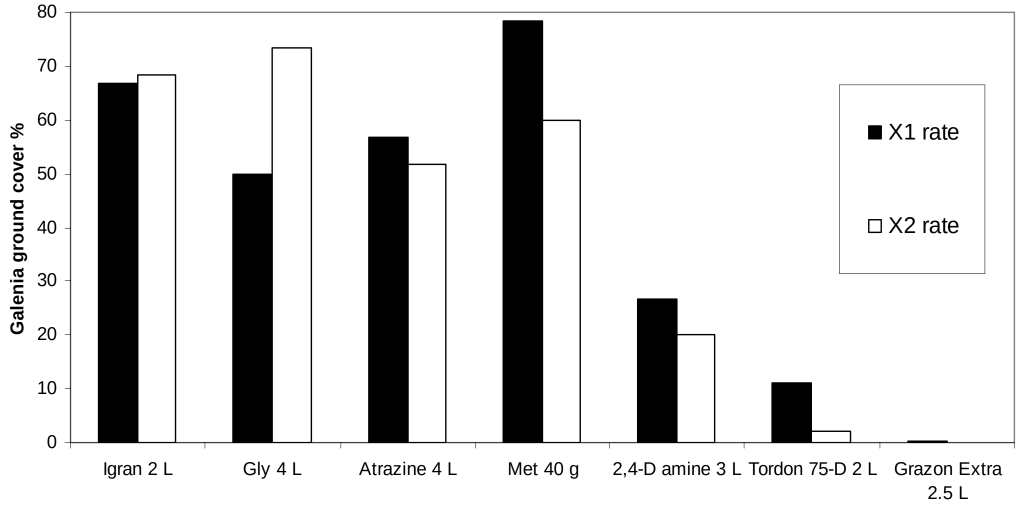

Figure 3. The effect of a double knocking herbicide treatment on galenia (a systemic herbicide followed by a desiccant herbicide) control, as measured by its proportion of pasture ground cover (assessed 139 days after treatment (DAT)). The desiccant treatment was paraquat (250 g L^{-1}) at 2.4 L ha^{-1}. The systematic or "first knock" herbicides applied were: Igran = terbutryn (500 g L^{-1}); gly = glyphosate (450 g L^{-1}); atra = atrazine (500 g L^{-1}); met = metsulfuron (600 g kg^{-1}); 2,4-D = 2,4-D amine (625 g L^{-1}); Tor 75-D = Tordon® 75-D (2 L ha^{-1}); and Gr Extra = Grazon® Extra (2.5 L ha^{-1}). Product rates indicated on the horizontal axis are the X1 rate per hectare).

Experiment 6 Impact of spot spraying
Grazon® Extra was the best treatment applied as a spot spray (Table 3). It took as much as 223 DAT to reach maximum control. There were some small plants surviving, but on the whole this treatment performed superbly. The preferred rate is between 125 and 250 mL 100 L^{-1} water. Rates above this would be seen as uneconomical; there was no extra control for the added cost (Table 3).

Esteron® LV, a non residual treatment, gave encouraging levels of control between 33 and 110 DAT. However, at the final assessment 223 DAT the only commercially acceptable treatment was the highest rate of 300 mL 100 L^{-1}. Levels of control from Tordon® 75-D seemed to peak around the 110 DAT period. However, like Esteron® LV, the only commercially acceptable rate was 300 mL 100 L^{-1} after the final assessment was made approximately seven months post-spraying.

Table 3. The effects of various spot treatments on the control of galenia. Control scores were assessed at various days after treatment (DAT). All treatments had Uptake® added at 0.5% v/v (500 mL 100 L^{-1} of water).

Herbicide	Product rate per 100L water	Control score 33 DAT	Control score 110 DAT	Control score 223 DAT	% control 223 DAT
Grazon® Extra	125 mL	3.5	3.8	5.0	88
Grazon® Extra	250 mL	3.8	4.8	4.8	96
Grazon® Extra	500 mL	4.3	4.8	5.0	96
Esteron® LV	75 mL	3.4	2.0	1.0	35
Esteron® LV	150 mL	3.6	3.4	2.0	84
Esteron® LV	300 mL	3.9	4.5	2.7	93
Tordon® 75-D	75 mL	2.8	2.8	2.6	65
Tordon® 75-D	150 mL	2.9	2.6	2.7	60
Tordon® 75-D	300 mL	3.8	4.2	3.5	90
Hotshot®	125 mL	1.6	2.2	2.0	45
Hotshot®	250 mL	2.1	2.0	2.5	45
Hotshot®	500 mL	2.7	2.6	2.8	60
Metsulfuron (600 g kg^{-1})	5 g	4.3	3.7	2.8	85
Metsulfuron (600 g kg^{-1})	10 g	4.3	4.1	3.4	93
Metsulfuron (600 g kg^{-1})	20 g	4.5	4.7	4.2	98
Glyphosate (450 g L^{-1})	250 mL	3.7	2.5	3.5	75
Glyphosate (450 g L^{-1})	500 mL	3.9	2.8	2.5	79
Glyphosate (450 g L^{-1})	1 L	4.0	2.5	2.8	75
LSD ($P<0.05$)		0.4	0.6	0.7	14

Hotshot® at rates of 125 to 500 mL 100 L^{-1} water were not adequate enough to control galenia. Peak control from metsulfuron was achieved between 33 and 110 DAT. Rates of 10 or 20 g 100 L^{-1} of water resulted in satisfactory control. This herbicide was slightly less efficacious than Grazon® Extra and could be used as an economical tank mix component to improve control as its selectivity towards competitive pasture grasses make it a worthy spot spray treatment.

Glyphosate is not a recommended spot spray treatment for galenia because of excessive pasture damage and the short term control that resulted. All glyphosate-treated plots had recovered somewhat after 110 DAT, and it appears control was not strongly related to glyphosate application rate.

DISCUSSION

This research has shown there are many new treatments that have merit for registration or minor use permit application for the management of galenia. Those treatments will reduce costs, maintain efficacy and lessen damage of nearby sapling eucalypts and acacias. With the granting of an APVMA permit, those managing galenia will have an excellent selection of treatments to suit their needs.

Aminopyralid is the additional active ingredient in Grazon® Extra (with picloram and triclopyr). However, Grazon® DS does not have this active ingredient. The additional aminopyralid might be the reason why Grazon® Extra works extremely well at rates between 0.8 and 2.5 L ha^{-1}.

Paraquat has some potential for galenia control. Although not reported in this paper, repeat applications of paraquat have a moderate effect on galenia and may have a role to play in lucerne production. Although there appeared no benefit between increasing the rate from 1.2 to 2.4 L ha^{-1} for a single application, this rate increase was more beneficial with repeated applications.

The technique of double knocking with paraquat (after a systemic herbicide is applied) did not give additional control over the conventional one-pass application of a systemic herbicide. Furthermore, a second knock with paraquat is likely to temporarily damage desirable pasture species which would provide some competition against galenia. This finding is contrary to double knocking research on many other species in cropping areas of Australia and therefore should be re-evaluated in future experiments.

Various herbicides used in these experiments have the potential to cause off-target damage to trees such as eucalypts and shrubs such as acacias. Grazon® products (Extra and DS) were associated the highest levels of damage, depending on the rates used (data not shown).

There are some additional areas of research that need further investigation. Variable control efficacy with glyphosate and metsulfuron is one of these. The variable control is likely to be due to moisture stress and seasonal effects, but, as yet, we are unsure which of these factors plays the major role.

Basic ecological information is lacking with respect to seed bank longevity of glaneia. Furthermore, as a form of integrated weed management, research aimed at using optimal herbicide technology along with best pasture management should drive better longer term galenia control.

This research provides critical information for an application of a minor use permit application to the Australian Pesticides and Veterinary Medicine Authority (APVMA).

ACKNOWLEDGEMENTS

The results presented in this paper would not have been possible without the following people and organisations; Steve Clarkson (Hunter Catchment Management Authority) Adam Spargo and Scotney Moore (Ashton Coal), Rebecca Miller (New South Wales Department of Primary Industries), Doug Campbell (Upper Hunter Weed Authority) and various staff from Dow AgroSciences.

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SNAPPING GOOD TIME WITH ALLIGATOR WEED
Removal of alligator weed in residential backyards

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SUMMARY This presentation will describe how Albury City Council detected and treated one of two terrestrial backyard infestations of *Alternanthera philoxeroides* (Mart.) Griseb. (alligator weed). In 1996 NSW Agriculture and Local Government embarked on a state-wide search after detecting alligator weed in residential backyards. Alligator weed looks similar to the Sri Lankan vegetable Mukunuwenna or Poonankani, and was identified in more than 30 backyards throughout NSW after it was mistakenly planted in residential gardens. Fifteen years on, after pulling together a history of alligator weed in the Riverina, Paula Bosse, Riverina's Noxious Weeds Project Officer, confirmed infestations had been detected in Albury, Culcairn, Griffith, Hay, Narrandera and Wagga during the 1996 search. This information has led to detection of a new residential infestation in Wagga Wagga and two in Albury.

Albury City inspected eight backyard locations, where two properties still had alligator weed growing. After inspecting the backyards and neighbouring properties, a control program was implemented for the two infested properties. This involved working closely with the owners of the properties to get a good result of the removal of the alligator weed. Council chose to undertake mechanical removal (with excavator and bobcat) and this paper will detail the process undertaken from the *Alligator Weed Control Manual* which is supplied by the NSW Department of Primary Industries. Factors covered include the importance of keeping a job site clean so that there is no removal of unwanted plant material; along with the removal and disposal technique from the start of digging to the disposal at the waste management centre; finishing up with the final wash down of all vehicles, equipment and site area.

Keywords: Alligator weed, Mukunuwenna, mechanical removal techniques.

REMOVAL TECHNIQUE

The first inspection was carried out on the 29th March 2012, it was noted that there were infestations of alligator weed growing in the lawn area of both a Kokoda Street property and a McDonald Road property in Lavington. It was located in three areas of the backyard: along the fence, in the middle of the lawn and where the residents were dumping their grass clippings. Further inspections were conducted on other properties close to the infestation, with no infestations detected. Photos were taken and a sample sent to the Herbarium in Sydney. Background information was gathered from the previous owners who grew it in a vegetable patch for their cooking. A second inspection was carried out on the 20th July 2012 and it was noted that frost had burnt the alligator weed off so the decision was made to remove the alligator weed in the summer months when it is actively growing.

On the 17th January 2013 discussions with a local earth moving contractor were held on site to discuss the process and cost to manually removal the alligator weed. A 25 tonne excavator on site at the landfill, a 3 tonne Mini excavator, a Positrack bobcat and a 4m^3 truck were used to cart the weed material away and supply topsoil to backfill. A deed of agreement was drawn up between the residents and Council for the removal of the alligator weed in their backyard. Council also drew up and implemented a traffic control plan for the work site. The

"Dial Before You Dig" referral service reported no underground utilities in the proposed removal areas.

On the 20th February 2013 the Vegetation team had a tool box meeting to discuss all safety and risk assessments of the job including the safety of all staff concerned and traffic control on the work site for the safety of the general public. Processes were put in place to eliminate any hazards that were identified during the removal of the alligator weed. Each staff member involved was delegated relevant tasks which ensured that the removal went without any incidents.

A pit was dug at the landfill site, with the dimensions of 10m long, 5m wide and 2m deep. The site was to be lined with black plastic and then covered with soil and over the next few months covered with 20m of rubbish and fill. A site induction was conducted at the Kokoda Street site after the traffic control plan was put in place. The alligator weed was dug out using the mini excavator and the first area was dug 2m wide, 8m long and approx. 600cm deep. The roots of the weed were followed down until no more fibres could be found. The soil was thick and heavy with clay, with no top soil. The second area was 2m wide, 2m long and 600cm deep. The third area was where the residents were dumping their grass clippings, an area of 4m long, 3m wide by 35cm deep. This area was scrapped of all the loose grass clippings and any soil that had built up over time.

After the pits were finished they were lined with a green tree root barrier. All loose soil was scraped up and tarped down on the truck for removal to the landfill. Council's 5000-litre water tank was used to hose and clean down all vehicles and equipment on site. This was done at the end of each day to eliminate any pieces of alligator weed from escaping. The area was hosed each day to stop the dust as it was very dry. All plant and equipment at completion was washed down on the dirt area of the backyard and inspected before leaving the site. The property was monitored over the next few months and will continue over the coming years. If any new plants are found they will be dug up and removed. All areas were checked and photographed before and after the works were started and completed.

On the 21st February 2013 another site induction was conducted at the Kokoda Street property with the traffic control plan in place. The excavator was washed down and cleaned in the backyard before leaving the site. The contractors supplied top soil to back fill the area dug out. This was dumped at the front of the property and moved in with the bobcat. The area was filled and levelled with the bobcat and then a final rake over by Parks and Gardens staff.

Once it was all level the bobcat was washed and cleaned down for removal from site. The driveway was washed down and the entire area cleaned. The back lawn area was re-seeded with a lawn blend mix. After a final inspection, the site was handed over to the residents. Follow up inspections will take place over the next few months and the coming years.

ACKNOWLEDGMENTS

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COMPARISON OF USE RATES AND TREATMENT TIMING WITH GLYPHOSATE TO CONTROL MEXICAN WATER LILY

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SUMMARY Mexican water lily (*Nymphaea mexicana* Zuccarini) is a perennial emergent aquatic plant that originates from Mexico and southeastern USA. It has established in Northern Victorian waterways and is a nuisance in the Goulburn Weir, Benalla Lake and the Gunbower Creek. The Lily has rapidly colonised these shallow nutrient-rich waters and formed dense infestations. In some situations they have formed a physical barrier limiting flushing of backwaters with river water (that contains higher concentrations of dissolved oxygen). Further, they reduce oxygen transfer from the atmosphere into the water due to blanketing, add organic matter to the water column stimulating biological activity that deplete dissolve oxygen levels, contribute to siltation and decrease the economic, recreational and environmental values. In spite of the significant negative effects, the plant is not declared as a noxious weed in any jurisdiction.

Following the continued expansion of Mexican water lily, and associated concerns about low dissolved oxygen, a research program was established. The program assessed the rate of dieback and regeneration when treated with of glyphosate at ½ and full label rates (3 and 6 L ha^{-1} of Weedmaster Duo) when applied at intervals from spring to autumn. A treatment strategy was developed to minimize the potential for low oxygen levels in the water and maintain control of Mexican water lily.

Time of application significantly affected the speed of dieback and regeneration, with the treatment during late summer/autumn resulting in the longest duration of low Mexican water lily cover. Application at this time also increased the potential for oxygen exchange between water and atmosphere and reduced the barrier between the river channel and the back water. There were no differences in rate of dieback or regrowth attributed to herbicide rate.

Keywords: *Nymphaea Mexicana*, herbicide, dissolved oxygen.

ALLIGATOR WEED IN THE NAMOI RIVER – A THREATENED SPECIES

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SUMMARY Alligator weed (*Alternanthera philoxeroides*) is one of Australia's worst aquatic weeds with infestations difficult and expensive to control. During April 2012 alligator weed was detected in the Namoi River near Gunnedah, NSW and in March 2013 further infestations were found in the Peel River and Sandy Creek - a tributary of the Peel River near Somerton. These are the first known infestations of alligator weed in these river systems. After the initial finding at Gunnedah a taskforce was established to formulate a management plan. This taskforce involved representatives from Gunnedah, Narrabri and Liverpool Plains Shire Councils, Tamworth Regional Council, The Namoi Catchment Management Authority (CMA) and New South Wales Department of Primary Industries (NSW DPI). Financial support for the management of these infestations was provided by the CMA and NSW DPI with funds allocated for surveillance, control, education and community awareness activities. Although these infestations have proven challenging to delimit and control, the management efforts undertaken present an effective model of cooperative planning and implementation between weed control authorities and state agencies.

Keywords: Aquatic, Cooperation, Identification training, community involvement.

INTRODUCTION

During surveillance of the Namoi River near Gunnedah in April 2012, a weeds officer from Gunnedah Shire Council who had recently undertaken water weed identification training discovered a suspicious plant that was identified as alligator weed by the NSW herbarium. Until this detection only three alligator weed infestations were known west of the Great Dividing Range, two in farm dams near Albury and Mudgee, and one in Barren Box swamp and the surrounding Wah Wah irrigation district near Griffith.

In March 2013 weeds officers from Tamworth Regional Council and Gunnedah Shire Council continued surveillance with the aim of locating the source of the alligator weed plants found in the Namoi River. This work led to the discovery of alligator weed in the Peel River near Somerton and in Sandy Creek- a tributary of the Peel River.

Due to alligator weed's invasive nature and its potential threat to the environmental, economic and recreational value of the Namoi and Peel River systems, a meeting of stakeholders occurred to discuss the management options. This meeting culminated in the establishment of a taskforce to oversee the management of the alligator weed infestation. This taskforce involved representatives from Gunnedah, Narrabri and Liverpool Plains Shire Councils, Tamworth Regional Council, the Namoi CMA and NSW DPI (Figure 1).

Figure 1. Members of the taskforce inspecting alligator weed on the banks of the Namoi River. Left to right Tony Woods, Clare Felton Taylor, Lee Amidy, Charlie Mifsud, Troy Crittle and Michael Whitney. Photo: Peter Scott

DEVELOPMENT OF A MANAGEMENT STRATEGY

The taskforce first met at Gunnedah in June 2012 and undertook to develop a Namoi Valley Alligator Weed Strategy Action Plan (Table 1). The goal of the Action Plan was to eradicate alligator weed from the Namoi catchment and involved a delimiting survey, inspection of high risk sites, prompt treatment of all infestations, maintenance of detailed records and an awareness campaign.

IMPLEMENTATION OF THE MANAGEMENT STRATEGY

Immediately after identification, Gunnedah Shire Council commenced a delimiting survey to establish the extent of the infestation. Waterways within the Gunnedah Shire - primarily the Namoi River, its associated tributaries and the foreshores of Lake Keepit – were surveyed. The survey was completed within 4 weeks of the positive identification of alligator weed. Eleven additional alligator weed plants were found over a distance of 63 kilometres in the Namoi River between the junction of the Namoi and Peel Rivers and a site 18 kilometres downstream of Gunnedah. Once established, representatives from all the local and state government agencies on the taskforce became involved with follow up surveys. Surveillance was undertaken twice in 2012 and again in early 2013 with the foreshores of Lake Keepit inspected in addition to 60 kilometres of the Namoi River from the Lake Keepit wall to the Gunnedah township.

Table 1. Namoi Valley Alligator Weed Strategy - Action Plan to eradicate alligator weed from the Namoi catchment.

Objective 1	
Detect and treat all alligator weed infestations in the Namoi Catchment by April 2013	
Delimit infestation	Conduct delimitation survey of catchment using process of elimination
Inspect high risk sites	Conduct one full inspection of catchment between locations of the most upstream and the most downstream infestation sites annually.
Identify invasion pathway	Identify infestation source
Intercept and eliminate invasion pathway	Destroy infestation source
Treat new infestations promptly	New infestations treated within 48 hours of discovery
Maintain detailed records	Maintain records of infestation sites and initial treatments
Objective 2	
Monitor effectiveness of eradication campaign	
Known infestations regularly reinspected	Reinspections made quarterly
Follow-up treatments made promptly	Treatments made on day of inspection
Maintain detailed records	Maintain records of treatments undertaken and of effectiveness of previous treatments
Objective 3	
Increase community involvement in alligator weed surveillance	
Engage adjacent landholders	- Press articles - Mail outs - Field days - Displays
Identify other stakeholders	
Engage other stakeholders	- Press articles - Talks at club meetings - Mail outs

Each surveillance exercise was undertaken over several days with the river broken up into segments that could be covered in a day by a two person team using either a boat or kayaks. In March 2013 a helicopter was used by Gunnedah Shire Council to undertake surveillance of farm dams in the vicinity of Lake Keepit and the Namoi River. No alligator weed infestations were found in this surveillance.

All plants located during the Namoi River surveys were plotted using GPS and mapped. Immediately after the completion of each survey, control of the located plants was undertaken by members from the Councils involved in the taskforce and the CMA. Post treatment, regular inspections of treated sites were undertaken to evaluate the effectiveness of the control efforts and to remove any remaining plant fragments.

The alligator weed infestations in the Peel River and Sandy Creek are located in Tamworth Regional Council's area. Surveillance and control of the alligator weed located on these waterways was undertaken by Tamworth Regional Council weed officers with the assistance of staff from the Namoi CMA and Gunnedah Shire Council.

Surveillance of the Namoi River and its tributaries between Gunnedah and Narrabri was undertaken by members of the taskforce with several alligator weed plants located in Gunnedah Shire but none found in Narrabri Shire. To date 650 hours have been spent on surveillance and control in Gunnedah Shire and 700 hours in Tamworth Shire with 150 alligator weed plants found and treated.

In conjunction with the surveillance and control efforts a program of public awareness was undertaken including:

- press articles in regional newspapers,
- a television advertising campaign,
- a flyer drop to landholders in the area where the plants were found,
- field days and displays for landholders and potentially affected groups such as recreational fishers and
- information releases on evening news bulletins.

Funding for the alligator weed program was supplied by the Namoi CMA, NSW DPI, NSW Weeds Action Program and by the councils involved. During all these activities there has been good coordination between the agencies involved in the taskforce. Member agencies are involved in ongoing surveillance and awareness, and weed officers from all the councils and members of the CMA are involved in the control efforts.

FUTURE ACTIVITIES

Future activities will revolve around maintaining the taskforce and continuing the awareness, surveillance and control efforts. Locating and eliminating the source of the alligator weed infestation is a high priority. Funding is an issue due to the expense of finding and controlling alligator weed. Continued funding will be a priority if the alligator weed infestations in the Namoi and Peel Rivers are to be controlled.

CONCLUSION

The discovery of alligator weed in the Namoi and Peel Rivers in 2012 and 2013 is a major concern given that it is the first known infestation of alligator weed in the upper reaches of the Murray Darling River system, and the threat it poses to environmental, recreational and economic values of this river system. Fortunately the establishment of the taskforce and the cooperative way these infestations have been managed with local and state government agencies working together gives those involved the hope that these infestations can be eradicated.

ACKNOWLEDGEMENTS

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COMMUNITY INVOLVEMENT IN THE ATLAS OF LIVING AUSTRALIA: AS IT RELATES TO BIOLOGICAL CONTROL

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SUMMARY The Atlas of Living Australia (ALA) is a community accessible central database that captures data from important Australian biodiversity databases including those made by museums and herbariums. All living organisms such as plants, fish, birds, snakes, insects etc. recorded in Australia are included. Information on organisms and their distribution can be easily obtained and mapped.

The Weed Biological Control (WBC) Portal and has been developed on the ALA infrastructure and aims to provide a central repository of weed biological control data. It contains information on weeds, weed biocontrol agents, where agents are established, their availability and redistribution methods. There is also a comprehensive field guide of biocontrol agents to enhance agent recognition with links to many other resources. This is an interactive site and everyone is encouraged to record, map and download weed biological control agent sightings.

This paper presents an overview of the ALA and WBC Portal and provides necessary information so that all community members are able to practice weeds biological control methodology.

Keywords: Atlas of Living Australia, weeds, biological control, biocontrol agents

INTERCONNECTIONS AND INVASION
What it means for local biodiversity

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SUMMARY Invasive species and habitat loss are widely acknowledged as the major contributors to biodiversity decline worldwide. Native ecosystems that are surrounded by agricultural practices and urban development are threatened by a number of processes including invasive species, land clearing, and inappropriate fire regimes. Located in the South West Slopes of NSW, Albury is surrounded by large areas of connected Box Gum Grassy Woodland habitat (an Endangered Ecological Community) that supports a number of significant flora and fauna species. The decline of Albury's woodlands and its associated biodiversity is a complex issue, with interconnections existing between many of the key processes that threaten their persistence. The devastating impacts to flora and fauna from weed invasion in Albury's woodlands is often exacerbated by other threatening processes such as land clearing, firewood collection and pressure from other invasive species. Land managers can therefore no longer address threats to biodiversity (such as weed invasion) in isolation. There is also a demonstrated need for all landholders to have a greater understanding of the interactions associated with key threatening processes in the role of biodiversity decline.

Keywords: habitat loss, grassy woodlands, key threatening processes, weed invasion, biodiversity decline.

INTRODUCTION

Habitat loss, modification and fragmentation are major causes of biodiversity decline worldwide (Lindenmayer and Fischer 2006, Polyakov *et al.* 2013). This is especially relevant to Australian landscapes as many of the temperate woodlands have been extensively cleared, fragmented and degraded since European colonisation (Prober *et al*. 2005, Polyakov *et al*. 2013). Livestock grazing and cultivation for agricultural production has led to the invasion by exotic annuals of many remaining remnant woodland areas (Maron and Lill 2005, Prober *et al*. 2005). The resulting loss of deep-rooted perennials has also contributed to other landscape scale problems such as salinity, erosion and tree decline (Prober *et al.* 2005).

BIODIVERSITY ON A LOCAL SCALE

The Albury area, located in the south west slopes of New South Wales was colonised in the early to mid 1800s. By the late 1800s most of the Albury Ranges woodlands had been cleared for grazing (Kavanagh *et al*. 2007). Although the Albury Ranges were almost completely cleared of tree cover, the area was set aside as a public reserve in the early 1900s and as a result, the ranges were left to regenerate (Albury City Council 2012). The resulting woodland regeneration (Figure 1) is listed as Box Gum Grassy Woodland, an endangered ecological community under the Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999 and the NSW *Threatened Species Conservation Act 1995*. The understorey of this community is highly diverse and contains flora that is now relatively rare elsewhere in the South West Slopes bioregion (DECCW 2009).

Figure 1. Vegetation present in the Albury Ranges that consists of the Endangered Box Gum Grassy Woodland community. The photograph shows extensive regrowth and a vast understorey after the clearing of the hills in the late 1800s.

WEED INVASION AND INTERACTIONS

Weed invasion from the surrounding agricultural region is a serious threat to the biodiversity of the Albury Ranges (Albury City Council 2012). For example, Kangaroo Grass (*Themeda triandra*) is a dominant feature of the Box Gum Grassy Woodlands (Cole *et al.* 2004), and this species has been lost from many areas of remnant woodlands through disturbances such as grazing. Remnants then become dominated by annual weed species that outcompete native species and change habitat conditions; leading to reduced overall diversity (Prober and Lunt 2008).

Deleterious effects of livestock grazing on the biodiversity of grassy woodlands may be increased by the interaction of weed invasions. Together with weed invasion, livestock modify habitats (Dorrough *et al.* 2012), can reduce structural complexity of habitats (Pollock *et al.* 2005) and have been found to effect terrestrial invertebrate fauna abundance and composition (Maron and Lill 2005). Figure 2 provides an example of an area of the Albury Ranges where structural complexity of the community has been reduced, resulting in the invasion of *Cytisus scoparius* (L.) (English broom) and exotic annuals. The interconnections of disturbances such as the combined effect of weed invasion and grazing however are not well understood for all species present in grassy woodland ecosystems. For example, few studies have considered the potentially negative impacts of excluding grazing in highly disturbed remnants (Maron and Lill 2005). Unexpected changes can also arise from excluding grazing from grassland habitats. Grazing was excluded from a grassland habitat on Santa Cruz Island in the US during a period of increased rainfall. This resulted in a sudden increase in resource availability and led to the expansion of an invasive plant species and feral pigs (Erskine Ogden and Rejmánek 2005).

Just as agricultural practices can change the structure of communities through weed invasion, changes in fire regimes can also influence the floristics and structure of vegetation (Driscoll *et al.* 2010, Fisher *et al.* 2009; Puglisi *et al.* 2005, Van Dyke *et al.* 2007) and contribute to a decline in biodiversity. Changes to community structure from fire can promote the invasion of exotic species, resulting in increased fuel loads in a short time frame (Fisher et al. 2009). In already degraded grassy woodland systems however, fire may be used to break the cycle of exotic seed bank replenishment and seedling establishment in fire-intolerant annuals through spring-time burns. This may help to promote native perennials that have evolved with fire to re-establish (Prober *et al.* 2005).

Habitat loss through agricultural practices and subsequent weed invasion can also lead to population declines of native fauna that depend on grassy woodland ecosystems (Michael *et al.* 2004, Maron and Lill 2005). Disturbances to habitat from agricultural practices alter the structure of vegetation on and near the ground, which is likely to influence the availability of invertebrate prey for some species of ground-dwelling woodland birds (Maron and Lill 2005). The issue of habitat loss is further complicated for a woodland bird species such as the Bush Stone-curlew (*Burhinus grallarius*) by the interactions and interconnections of other disturbances. Bush Stone-curlews are ground dwelling birds that have suffered major population declines and range contraction and fox predation has been suggested as the major cause of this decline (Gates and Paton 2005). As weed invasion changes habitat structure it is likely that the effectiveness of the Bush Stone-curlew's camouflage ability is reduced and its susceptibility to predation by introduced predators such as foxes is increased.

Figure 2. Vegetation present in the Albury Ranges where structural complexity has been reduced, resulting in the invasion of *Genista monspessulana* (L.) (Cape broom) and exotic annuals.

MANAGEMENT IMPLICATIONS

Key threatening processes do not often operate in isolation. The devastating impacts to flora and fauna from weed invasion in Albury's woodlands is frequently exacerbated by agricultural practices as well as other threatening processes such as land clearing, firewood collection and pressure from other invasive species. In order to protect local biodiversity, there is a need to recognise the importance of remnant woodlands in the Albury region (Kavanagh *et al.* 2007) and to improve the quality of the landscape 'matrix' around remnants (Kavanagh *et al.* 2007, Polyakov *et al.* 2013). Improving the surrounding matrix will allow the development of landscapes with a mosaic of different habitats whilst maintaining agricultural management (Pollock *et al.* 2005).

Managers of land containing the endangered box gum grassy woodland community need to consider an integrated approach. As many of the threats to biodiversity are interconnected, land managers can no longer address these threats (such as weed invasion) in isolation. Management regimes for the disturbed interfaces between the box gum grassy woodland and agricultural or peri-urban areas should consider simultaneous control of further weed spread, crash grazing, ripping or scalping, patch burning and revegetation (Spooner *et al.* 2002).There is also a demonstrated need for all landholders to have a greater understanding of these interactions associated with key threatening processes in the role of biodiversity decline. Educating landholders to understand that addressing threats together will help to protect intact areas, as well as help to restore partly degraded areas that contain existing seed banks and biodiversity value.

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WHY ARE WE TRYING TO STOP WEEDS?

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SUMMARY It is important to remind ourselves why we work on weeds. Contrary to recurring claims that weed control is motivated by xenophobia, we know that the future health of our landscapes and survival of many rare species depends on this work. Drawing on its soon to be published *NSW State of the Weeds Report*, the Invasive Species Council reviews the multitude of ways in which weeds threaten the environment and looks specifically what's at stake. The beneficiaries of weed control include many of the 40% of NSW's listed threatened species and the 90% of endangered ecological communities adversely impacted by weeds. They include national parks and waterways and wetlands. They include farmers, for whom weeds are the most costly natural resource management problem. We need to be much more vocal in advertising the damage done by weeds and promoting the value of the work done to protect our great natural assets from weeds.

Poster papers

GENETIC VARIATION IN SOLANUM ELAEAGNIFOLIUM IN AUSTRALIA USING SSR MARKER[A]

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SUMMARY Silverleaf nightshade (*Solanum elaeagnifolium* Cav.) is a problematic summer-growing perennial weed in Australia. The genetic diversity of silverleaf nightshade is poorly understood. Nine silverleaf nightshade specific and 10 cross-species simple sequence repeat (SSR) primer pairs were utilised to investigate the genetic variations among 94 silverleaf nightshade populations collected in Australia. High genetic diversity was found within silverleaf nightshade populations, with an average genetic similarity of 0.43. The Unweighted Pair Group Method with Arithmetic mean based dendrogram indicated the presence of genetically diverse silverleaf nightshade populations in Australia. However, no well supported genetic structure was found. The Mantel test indicated that there is no significant correlation between genetic variation and geographic distance. These results suggested a lack of geographic structure in genetic diversity, which is probably due to the long distance spread of seeds of silverleaf nightshade. The high genetic diversity of silverleaf nightshade could contribute to the inconsistency in control efficacy between populations.

Keywords: Silverleaf nightshade; invasive weed; cross-species SSR; microsatellites; genetic diversity.

INTRODUCTION

Silverleaf nightshade (*Solanum elaeagnifolium* Cav.) is a summer-growing perennial weed and is a Weed of National Significance in Australia (Australian Weeds Committee 2012). It is widely distributed in the cereal cropping zone in southern Australia, with potential to infest 398 million hectares (Kwong *et al.* 2006). It has been reported that silverleaf nightshade can cause up to 77% yield loss in cereals (Heap *et al*. 1997).

To date, classical biological control has not been implemented in Australia despite the species being declared a target for biological control in 1985 (Kwong 2006). In addition, the high regenerative ability of the root system has limited the efficacy of mechanical managements (Stanton *et al.* 2011), thus chemical control is the only useful option for silverleaf nightshade management in Australia. However, herbicide efficacy can be influenced by many factors including plant genetic variation (Marshall and Moss 2008). Therefore, effective management of silverleaf nightshade requires comprehensive assessment of genetic diversity (Dekker 1997, Holt and Hochberg 1997).

Genetic diversity studies have been conducted in many weed species, such as bitter vine (*Mikania micrantha* (L.) Kunth.) (Wang *et al*. 2012) and false helleborine (*Veratrum album* L.) (Treier and Muller-Scharer 2011). These studies contribute to the understanding of weed genetic diversity, evolution and invasion. Silverleaf nightshade was found to be

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genetically diverse in South Australia by random amplification of polymorphic DNA (RAPD) analyses (Hawker *et al*. 2006). However, the genetic diversity of silverleaf nightshade populations across Australia is largely unknown. Genetic diversity studies using genetic markers will contribute to the management of silverleaf nightshade (Dekker 1997).

Simple sequence repeat (SSR) markers are usually co-dominant, and more informative than dominant markers such as RAPDs because they are capable of differentiating homozygous individuals from heterozygous plants (Peakall 1997, McGregor *et al*. 2000,). Furthermore SSRs are more reproducible, easily scored and analysed on high throughput genotyping platforms. Thirty six SSR markers have recently been developed for silverleaf nightshade (Zhu *et al*. 2012, 2013). In this study, a subset of 19 high polymorphic primer-pairs was applied to study genetic diversity of 94 populations of silverleaf nightshade collected across Australia.

MATERIALS AND METHODS

Plant material

A total of 670 silverleaf nightshade individuals were collected from 94 locations (populations) in New South Wales, South Australia, Victoria, Queensland and Katanning in Western Australia (Figure 1). One to ten individuals were collected from each location, depending on the level of infestation. Sampled individuals were at least 50 m apart to reduce the probability of collecting clonal plants. In addition, five field samples of quena (*S. esuriale* Lindl., a native *Solanum* species), and five commercial samples of eggplant (*S. melongena* L.; Hortico, Australia), were included for comparison. About 1 g of fresh, undamaged leaf material was collected from each individual plant, placed in a 1.5 mL eppendorf tube, and then stored at -80ºC in the laboratory until DNA isolation.

DNA isolation

Genomic DNA was isolated individually and the quality and concentration was checked as described previously (Zhu *et al*. 2013). The individual DNA concentration was then adjusted to 20 ng μL^{-1}. Equal amounts of DNA from individuals representing the same population were bulked for PCR amplification, as a cost-efficient method of population analysis (Arunyawat *et al*. 2007, Eschholz *et al*. 2008).

PCR reaction and SSR analysis

Nineteen SSR primer-pairs (Table 1) were selected to investigate genetic diversity between populations, on the basis of their high expected heterozygosity value (H_E). The details of these primer-pairs have been described previously (Zhu *et al*. 2012, 2013). The 5' end of the forward primer of each SSR primer-pair was tailed with a M13 sequence to perform high throughput fragment analysis (Raman *et al*. 2005). PCR amplification and detection of the amplification products were carried out as described elsewhere (Zhu *et al*. 2013).

Data analysis

Binary data, as the presence or absence (1 or 0) of bands of each locus for each population, were scored to construct a similarity matrix by Jaccard's coefficient (Jaccard 1908) using NTSYS-pc 2.1 (Rohlf 2000). The Unweighted Pair Group Method with Arithmetic mean (UPGMA) was calculated using the Sequential, Agglomerative, Hierarchical, and Nested clustering (SAHN) methods of the same software to construct a dendrogram of population genetic relationships. Non-parametric bootstrapping (n=1 000 replicates) was used to estimate statistical support at detected clades, using the Paleontological Statistics Software Package (PAST) (Hammer *et al*. 2001). Correlations between genetic and geographical distance among all pair-wise population comparisons was tested by Mantel test using NTSYS, with 1 000 random permutations.

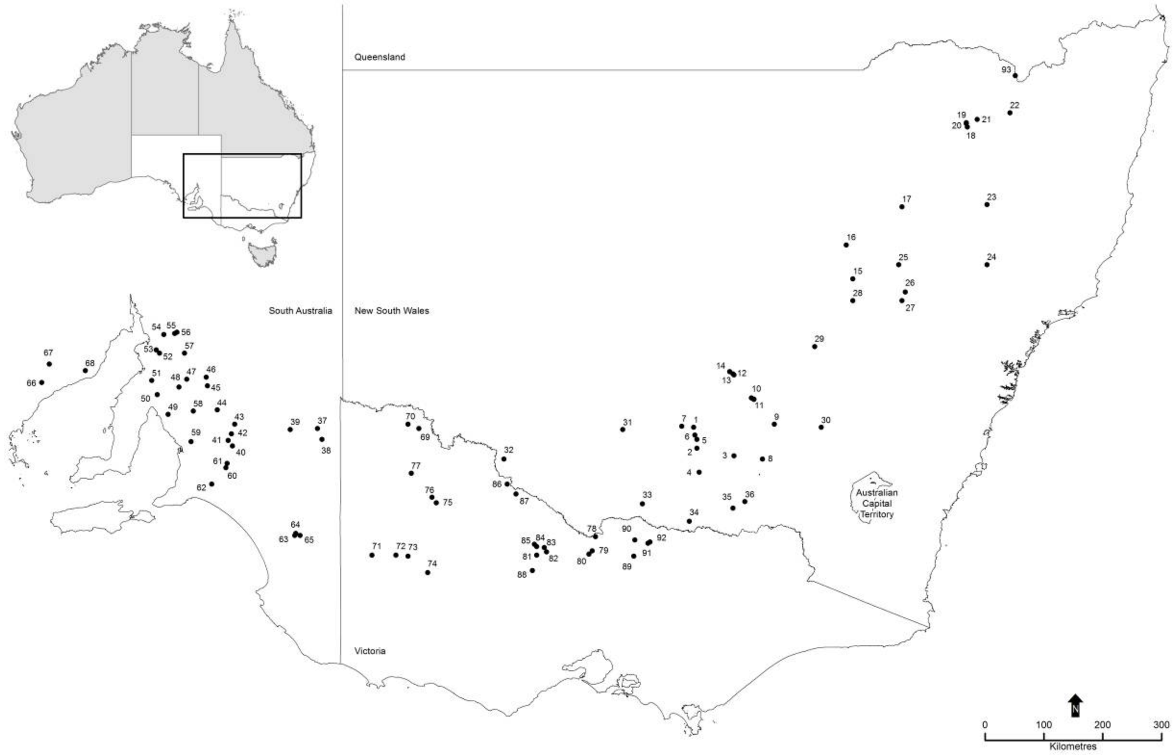

Figure 1. Sampling locations of silverleaf nightshade in New South Wales, South Australia, Victoria and Queensland (the Katanning, Western Australian population is not shown).

RESULTS AND DISCUSSION

The genetic diversity in 94 populations of silverleaf nightshade was assessed according to allele frequency. The SSR analysis illustrated a high level of genetic variation between silverleaf nightshade populations, with a total of 182 polymorphic bands (alleles) detected. The number of polymorphic bands varied from two with primer pairs SLNZ 8, SLNZ 17 and SLNZ 20 to 32 with the primer pair CA158, with an average of 9.6 polymorphic bands per locus (Table 1). The mean Jaccard's genetic similarity between populations was 0.43, varying from 0.21 to 0.76.

Bulk DNA analysis was used in this study. The reliability of bulk DNA analysis has been checked using a subset of individuals from nine locations (Zhu *et al*. 2013), which achieved similar results (average Jaccard similarity: 0.73 and 0.79 for the bulk and individual analysis, respectively). This method can lead to the loss of the co-dominant feature of SSR analysis and does not allow estimates of the heterozygosity within a population. However, individual genotype information was not essential for estimating between population genetic diversity (Dubreuil *et al*. 1999). The DNA bulking method is highly repeatable and reliable for population genetic studies, such as in maize (*Zea mays* L.) (Eschholz *et al*. 2008) and wild tomatoes (*Solanum peruvianum* L. and *S. chilense* (Dunal) Reiche) (Arunyawat *et al*. 2007).

The 19 SSR markers were successfully used to assess the genetic variation among 94 populations of silverleaf nightshade collected from different states of Australia. The present study detected a high level of genetic polymorphism among silverleaf nightshade populations within Australia, with a mean genetic similarly of 0.43. The high level of genetic variation in Australia might be attributable to multiple introductions (Cuthbertson *et al*. 1976), the heterogeneous nature of the initial introduction(s) and/or the self-incompatibility in silverleaf nightshade. Obligate outcrossing species usually have a higher level of genetic diversity than clonally or self pollinated species (Ward and Jasieniuk 2009).

Table 1. Simple sequence repeat (SSR) primers used to investigate the genetic diversity between three *Solanum* species, including the number of bands detected by each primer-pair and the corresponding allele sizes, including 19 base pairs (bp) of M13-tailed sequence[a].

Primer ID	Band number	Estimate allele size (bp)		
		S. elaeagnifolium	***S. esuriale***	***S. melongena***
SLNZ5	4	184 - 203	Fail[2]	188
SLNZ 6	4	256 - 279	Fail	Fail
SLNZ 7	7	226 - 255	Fail	248
SLNZ 8	2	196 - 202	160 - 196	160 - 197
SLNZ 15	4	174 - 187	174 - 187	183
SLNZ 17	2	162 - 164	174	164
SLNZ 20	2	236 - 238	218 - 220	241 - 249
SLNZ 22	14	174 - 246	242	242 - 248
SLNZ26	3	123 -147	160	166
CA158	32	217 - 264	277 - 239	249 - 255
ESM3	22	Null - 355	249 - 258	264 - 268
EM117	30	110 - 178	85 - 178	96 - 116
EM127	9	Null - 222	168 - 268	Fail
EM135	16	Null - 267	222 - 288	283
EM140	6	Null - 231	216 - 235	230 - 233
EM155	7	Null - 334	144 - 171	126 - 295
SSR111	7	Null - 180	174 - 176	183
STI001	4	205 - 217	205	213
STG0010	7	177 - 271	178	178

[a] Detailed sequence information is described previously (Zhu *et al*. 2012, 2013); [2]Fail: No amplification detected.

The Unweighted Pair Group Method with Arithmetic mean (UPGMA) dendrogram based on the Jaccard's coefficient clearly separated quena and eggplant from silverleaf nightshade populations and supported by high bootstrap value, suggesting the genetic variability among related species (Figure 2). The 94 populations of silverleaf nightshade were clustered into two main groups with low bootstrap support (<70%), which indicated no well supported structure was found in Australia (Figure 2). In addition, no significant correlation was found between genetic and geographical distance among populations (r = -0.03, t = -091 and p = 0.17). The UPGMA dendrogram and the Mantel test suggested that there is no geographical structure of genetic variation in Australian silverleaf nightshade populations. Similar results were found in other invasive species such as *Flaveria bidentis* Juss. (Ma *et al.* 2011) and *Parthenium hysterophorus* L. (Tang *et al.* 2009).

Long distance distribution of silverleaf nightshade is aided by the spread of fruits (seeds). Transportation of the contaminated livestock or fodder contributes to the dispersal of silverleaf nightshade populations. Such long-distance dispersal events may explain the lack of geographic structure of silverleaf nightshade in Australia. Seeds can generate new plants and hybridise with other genotypes, leading to gene flow, and this may have contributed to the high genetic diversity.

Weeds with high genetic diversity are more likely to develop new phenotypes in response to natural selection pressures, which allow better adaption to the environment or management practices (Dekker 1997). The high genetic diversity in silverleaf nightshade may have resulted in inconsistent management of this weed in Australia. Similarly, this study also suggests the important role of seed spread in silverleaf nightshade infestation. Attention should therefore be paid to stopping seed set and minimising the movement of agricultural products, livestock, and machinery.

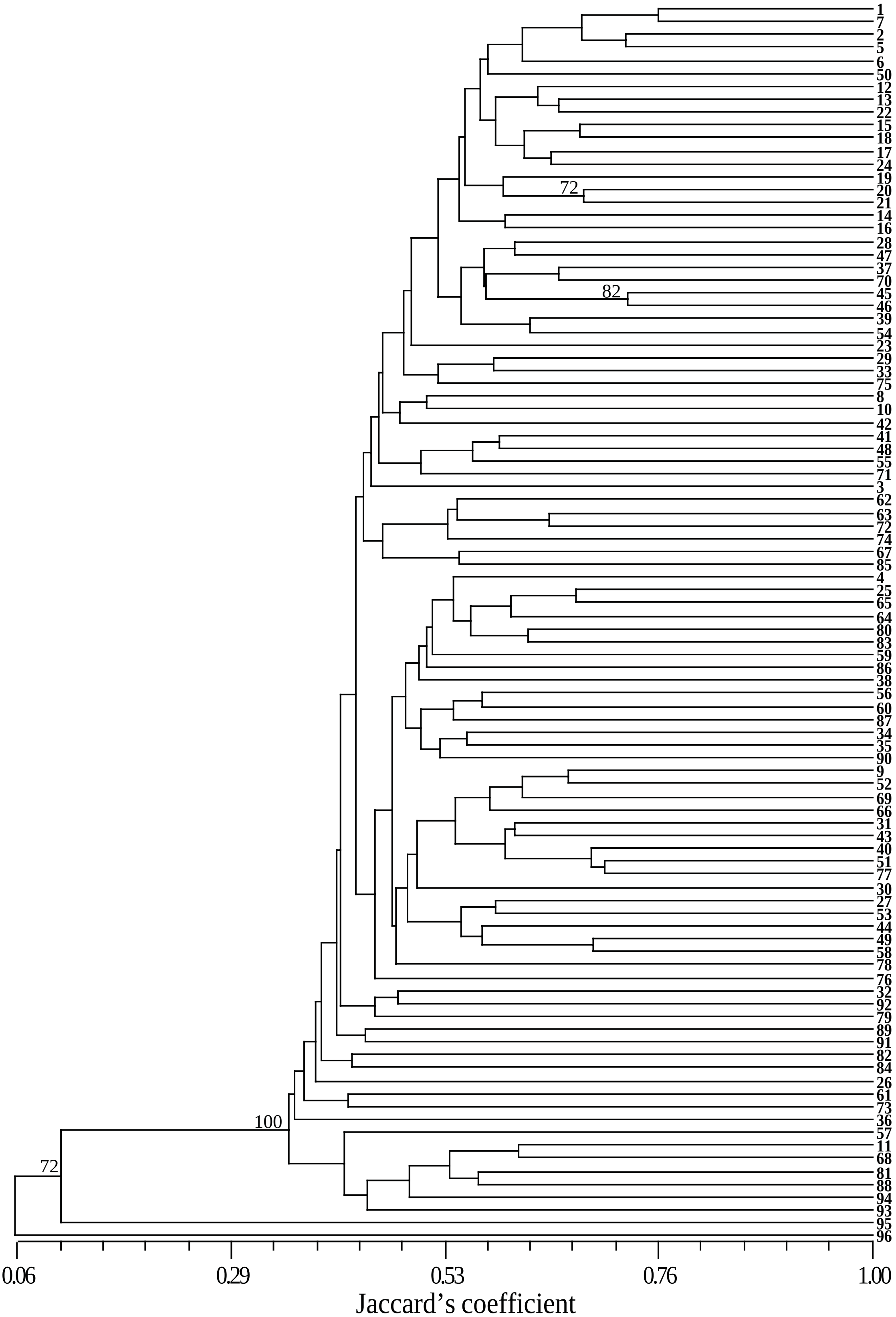

Figure 2. Unweighted Pair Group Method with Arithmetic mean (UPGMA) dendrogram of Jaccard's coefficient from dominant scored alleles of 94 Silverleaf nightshade accessions, quena (95) and eggplant (96) from Australia. Only bootstrap values >70% are indicated.

ACKNOWLEDGEMENTS

We would like to acknowledge the Charles Sturt University, Australia for funding this research. We thank a number of state and local organisations across Australia for their assistance in field sampling.

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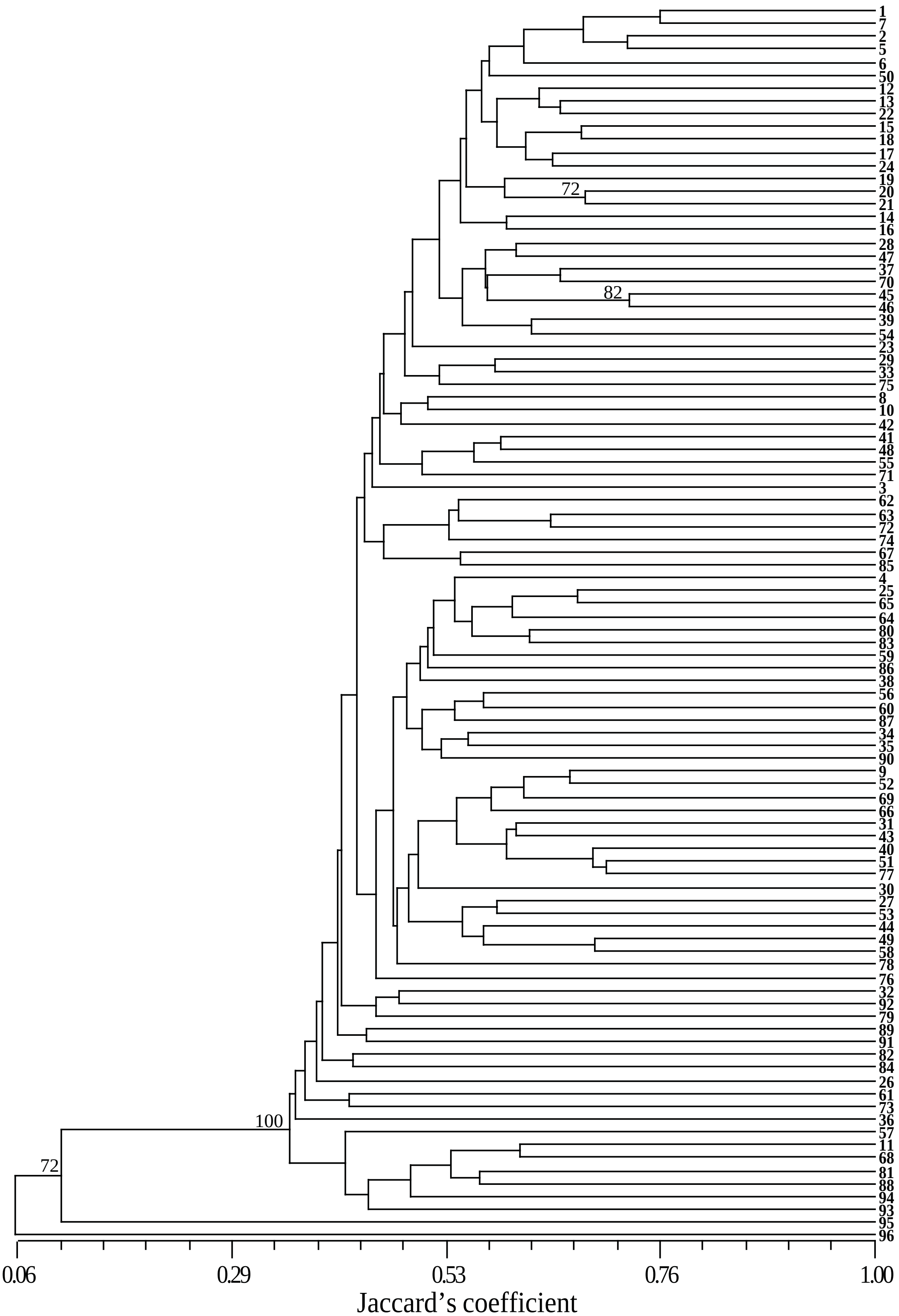

Figure 2. UPGMA dendrogram of Jaccard's coefficient from dominant scored alleles of 94 Silverleaf nightshade accessions, quena (95) and eggplant (96) from Australia. Only bootstrap >70% are indicated.

SMARTPHONES FOR EARLY DETECTION AND RAPID RESPONSE

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SUMMARY Environmental weeds can spread rapidly, so early detection and reporting is crucial. Reports of new environmental weed infestations need to be accurate, and timely. New generation Smartphones greatly facilitate the early detection and reporting.

Keywords: Mapping, smartphones and Apps.

INTRODUCTION

Planned surveys often use specialised mapping programs on laptops or note pads with protective cases. However field staff do not always carry such equipment when undertaking day to day work. But increasing numbers of staff do carry Smartphones. This means incidental observations can be recorded and the data sent from the field to the relevant Parks & Conservation employee or weed control contractor.

MATERIALS AND METHODS

Most new generation Smartphones have a high quality in-built GPS, which meets the need for accuracy. The GPS works with off-line mapping Apps such as Memory-Map (http://memory-map.com.au). Off-line maps are stored on the Smartphone allowing shapefiles to be created when there is no mobile data or Wi-Fi signal.

Large screen Smartphones such as the Samsung Note (screen size of 140.9mm or 5.5”, Figure 1), allow portability to be combined with a larger map view. These two features make recording in the field easier. An additional feature of a recording pen or stylus allows use with gloves and details to be added to screen grabs.

Smartphones allow photos, shapefiles and screen grabs to be attached to emails. Being able to do this with one device saves time and also encourages incidental reporting. Shock, dust and splash proof protection cases for Smartphones are available from companies like Otterbox. This makes field use practical.

Figure 1. A large screen Samsung Note in a protective Otter-box.

RESULTS AND DISCUSSION

Different types of GPS exchange format files (gpx files) can be generated using the Memory-Map App (Figure 2). The broad continuous lines at the top right of Figure 2 are tracks where the Ranger walked a slash line that had spread African Lovegrass. The flag is a waypoint of an isolated Chilean Needle grass infestation. The continuous line with interspaced dots is a drawn route indicating an area of St John's Wort to be sprayed. These gpx files were emailed from the field and later uploaded to the ArcGIS project, eWeeds, which maps all the ACT environmental weed control work.

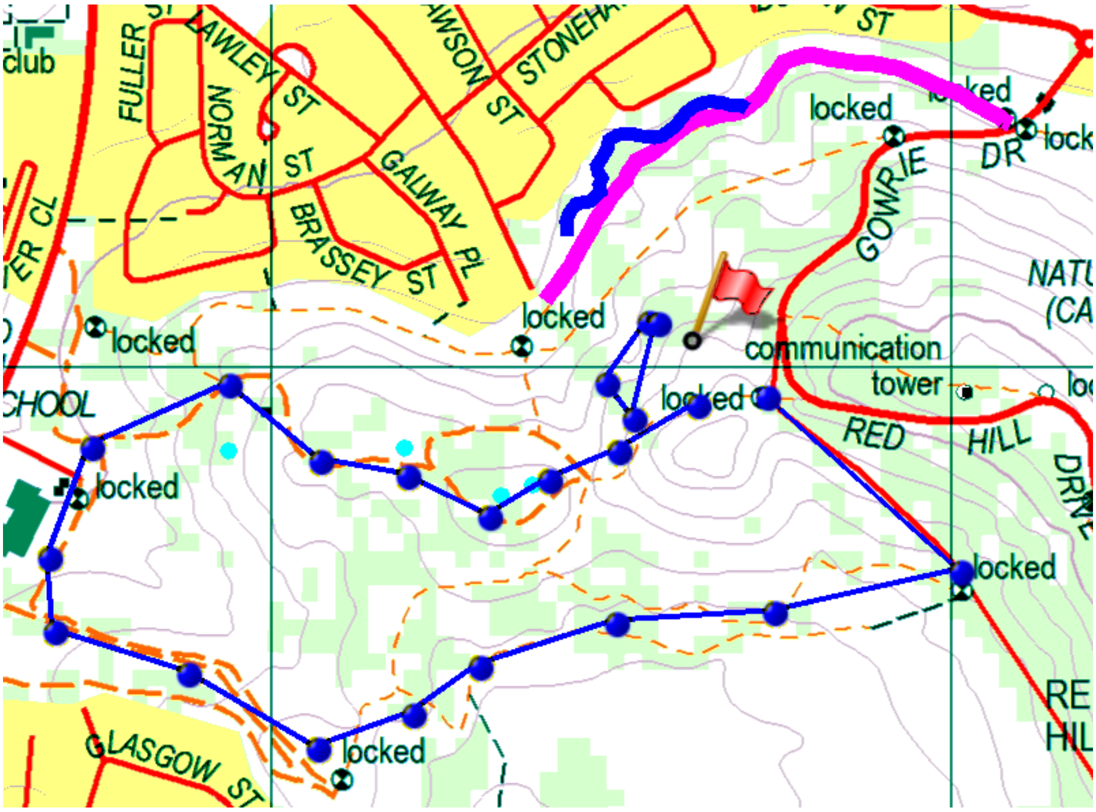

Figure 2. Examples of gpx files using the Memory-Map App on a Note Smartphone.

When a Parks & Conservation employee or contractor receives a new infestation email (Figure 3), the grid reference can be entered into a GPS or loaded as a gpx file into a Smartphone, which acts like a GPS (Figure 4). This allows easy navigation to the new infestation so it can be controlled. The time saved allows more on-ground weed control work to be undertaken.

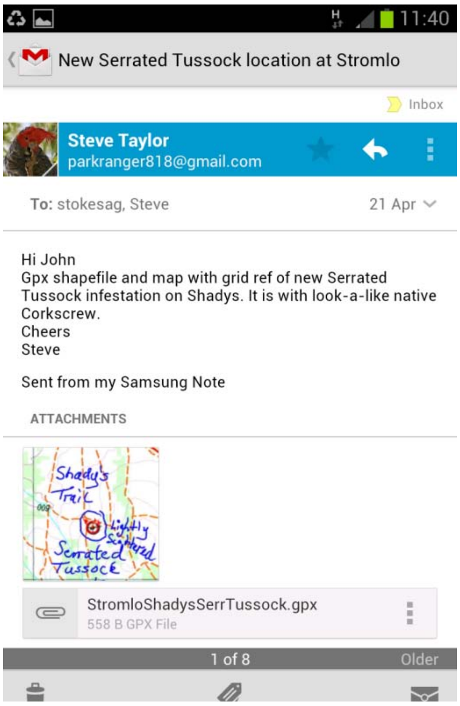

Figure 3. Email sent from the field to a contractor.

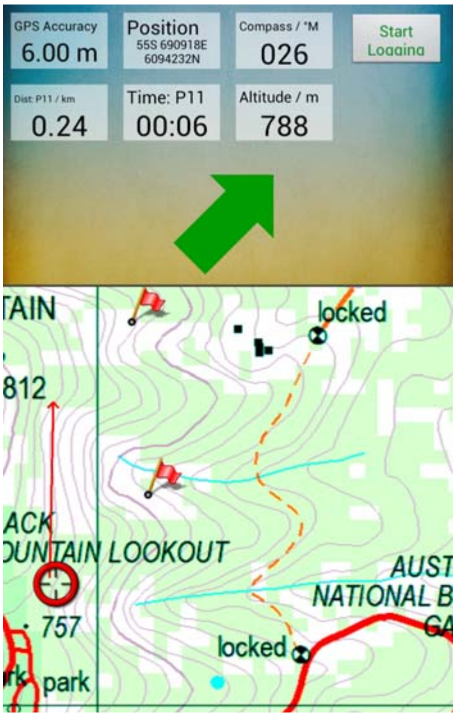

Figure 4. Navigation to a waypoint using the Memory-Map App on a Samsung Note Smartphone.

Another use for a Smartphone, running an off-line mapping App, is triangulation. Figure 5 shows how the location of a flare up during the Grampians bushfire deployment was mapped from a safe distance using the Memory-Map App on a Note. The screen grab and gpx shapefile can be sent from the field straight to the incident controller if required. In this case the grid reference was radioed through to the Parks Victoria Divisional Commander.

ACKNOWLEDGEMENTS

Special thanks to Lexi Williams, Fire Management Unit, ACT Parks and Conservation Service, for promoting the use of Smartphones for mapping. And also many thanks to Joshua Thomson, Natural Resource Protection Unit, ACT Parks and Conservation Service, for helping test shapefile creation using the Memory-Map App for uploading to the ArcGIS eWeeds project.

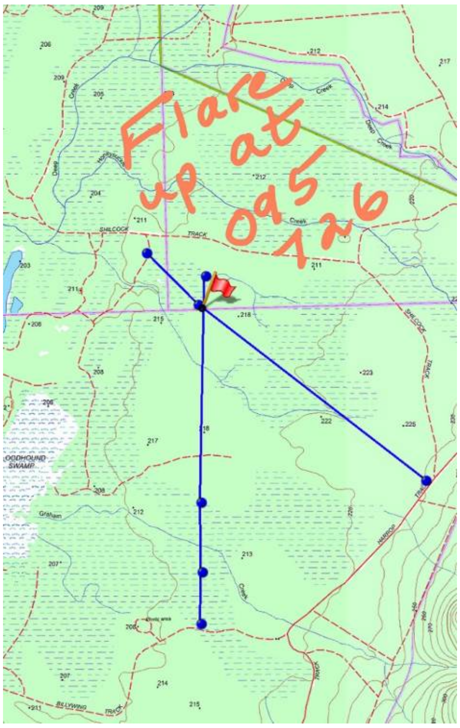

Figure 5. Triangulation using the Memory-Map App.

ENGAGING THE COMMUNITY
Invasive weed education in Canberra

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Engaging the community
Invasive weed education in Canberra

The spread of environmental or invasive weeds from home gardens has a significant impact on Canberra Nature Park nature reserves. The ACT Parks and Conservation Service and City Services have three education programs to reduce the spread of woody weeds and invasive grasses from home gardens.

- Weed Swap program;
- Floriade Bush Friendly Display Garden; and
- Garden Plants Going Bush brochure

Weed Swap – autumn and spring

Weed Swap is a partnership between the ACT Government and the Australian Native Plants Society. It allows Canberra residents to swap woody weeds removed from their gardens for non-invasive native plants.

Floriade Bush Friendly Garden

The Bush Friendly Garden is built by Parks and Conservation Service and City Services staff with support from ParkCare volunteers. This display garden receives thousands of visitors. It shows what plants to avoid or remove from gardens and provides examples of colourful non-invasive alternatives.

***Gardens Plants Going Bush* brochure**

This free brochure lists many of the environmental weeds found in home gardens or still sold by some plant nurseries. It is widely distributed to raise awareness of the species to avoid in home gardens.

ACT Government

Bush Friendly Display Garden, Floriade.

Minister for Territory and Municipal Services, Shane Rattenbury (centre) with ACT Parks staff and volunteers at the autumn Weed Swap, 2013.

Firethorn, one of the environmental weeds in the brochure.

NOXIOUS WEEDS ACT 1993 – MOVING WITH THE TIMES
What does this mean for you?

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SUMMARY Thorough and timely review of legislation is essential to provide a framework around which weed management activities in New South Wales (NSW) can continue to occur. Amendments to the NSW *Noxious Weeds Act 1993* (the Act) were made during 2012 following a five-year statutory review of the Act and a separate review in Primary Industries/Biosecurity legislation. This paper reviews the most significant outcomes from these separate reviews and briefly discusses the most important impacts the changes will have on weed management activities across the state.

Keywords: Legislation, objects, delegation, inspections, machinery.

INTRODUCTION

Although any plant that is in the wrong place at the wrong time could be considered to be a weed, only plants that have a significant impact on the economy, environment or community are candidates for declaration as 'noxious' under the *Noxious Weeds Act 1993*. By their spread, such weeds impose substantial and uncompensated costs on third parties who do not want these weeds spreading to land they manage (an externality). The *Noxious Weeds Act 1993* seeks to address this situation.

WHERE THE AMENDMENTS CAME FROM

The *Noxious Weeds Act 1993* has recently been amended to better reflect current weed management approaches and needs, for example through the New South Wales (NSW) Invasive Species Plan (NSW DPI 2008). Amendments were made in two significant pieces of legislation, these being the *Noxious Weeds Amendment Bill* (NWAB) *2012* and the *Primary Industries Legislation (Biosecurity) Amendment Bill* (PILBAB) *2012.* Amendments contained in the NWAB arose from a five year statutory review of the *Noxious Weeds Act 1993* while those from the PILBAB were part of a larger group of changes designed to amend multiple pieces of biosecurity legislation to ensure that emergency responses continued to be best-practice.

The following information covers some of the amendments and what they will mean for local government, other advisors and landowners/occupiers.

CHANGES MADE TO THE *NOXIOUS WEEDS ACT 1993*

Objects of the *Noxious Weeds Act 1993* - section 3

The objects of the *Noxious Weeds Act 1993* have been amended to the following (changes are underlined):

- prevent the establishment…of significant new weeds; and
- prevent, eliminate or restrict the spread….of particular significant weeds; and
- effectively manage widespread significant weeds…".

These changes help better recognise the many complementary biosecurity approaches needed to restrict the spread, and manage the impact of weeds across the state.

Delegation of local control authority powers - section 68

Previously section 68 of the *Noxious Weeds Act 1993* stated that

> "A local control authority may delegate to a person any of the local control authority's functions under this Act other than this power of delegation."

Some Local Government staff felt that delegation for noxious weeds functions (under the *Noxious Weeds Act 1993*) could be performed under section 377 of the *Local Government Act 1993* – General power of the Council to delegate).

This situation has been clarified so that section 68 now states (changes are underlined):

> "A local control authority may delegate to a person any of the local control authority's functions under this Act (other than this power of delegation) but only under this power of delegation."

Further clarification is provided in the note appended to this section which states:

> "Accordingly, a council may not delegate any of its functions as a local control authority under this Act under the council's power of delegation under the *Local Government Act 1993*."

This means that local government weed officers performing functions not directly delegated by section 68 of the *Noxious Weeds Act 1993* should alert their management to this amendment and seek new authorisations under the *Noxious Weeds Act 1993* **only**.

Strengthened powers to conduct inspections and investigations and to deal with suspect noxious weed material and its packaging - sections 44 and 47A

Inspectors and authorised officers now have broadened powers under section 44 to collect evidence and to remove or destroy anything reasonably suspected of being or containing noxious weed material when conducting inspections, such that the following sections now state (changes are underlined):

> section 44(c)
> "examine, take samples, photographs, or video recordings of, seize, detain, or remove any thing in or about those premises that the inspector or authorised officer reasonably suspects to be noxious weed material or to be vegetable matter, or any other thing, containing noxious weed material"; and
>
> section 44(h)
> "remove or destroy….any thing in or about those premises that the inspector or authorised officer reasonably suspects to be noxious weed material or to be vegetable matter, or any other thing containing noxious weed material".

Furthermore, new powers have been added to section 44, as follows:

> section 44(c1)
> "test, treat or disinfest any noxious weed material or any vegetable or other matter that the inspector or authorised officer reasonably suspects contains noxious weed material"; and
>
> section 44(j)
> "test, treat or disinfest any box, container, package or receptacle (including any place that could be used as a receptacle) in or about those premises that the inspector or authorised officer reasonably suspects contains any noxious weed material or vegetable or other matter containing noxious weed material".

Inspectors powers to determine the source and/or destination of noxious weed material have been strengthened with the following changes to section 47A (changes are underlined):

> "An inspector or authorised officer who reasonably believes that a person has information that may <u>assist in tracing or determining</u> the source or destination of <u>any matter that the inspector or authorised officer reasonably suspects to be</u> noxious weed material may require the person to answer questions for that purpose".

Expansion of the range of machinery/equipment that may be required to be cleaned before entering NSW - section 31
The section regulating the entry of machinery that may be carrying notifiable weed material has been expanded. The previous provision was restricted to agricultural machinery entering NSW from Queensland. This has been broadened to apply to any machinery or equipment specified by a Ministerial order and applies to entry to NSW from all states and territories.

In line with section 31, section 32 which prohibits the movement of machinery carrying notifiable weed material within NSW has also been expanded.

New powers to regulate or prohibit the bringing into NSW noxious weed material or things likely to introduce it – section 11
A new provision allows the Minister by an order published in the gazette to regulate or prohibit the bringing into NSW, or parts of NSW, noxious weed material, or any other thing considered likely to introduce such material.

Shortened time limit to notify the presence of notifiable weeds - section 15
The time limit for occupiers of land to notify the presence of notifiable weeds to the local control authority has been reduced from 3 days to 24 hours in line with the requirements of other Primary Industries biosecurity legislation.

Expansion of requirements to notify the presence of notifiable weeds - section 16A
A new section (16A) has been added to the *Noxious Weeds Act 1993* to broaden the reporting obligation of consultants/agronomists/advisors, departmental staff (including Local Land Services), council staff and contractors such that:

> "A person who, in a professional capacity, becomes aware or suspects that a plant on land is a notifiable weed must notify the local control authority for the land of that fact within 24 hours of becoming aware or suspecting that the notifiable weed is on the land"

A notifiable weed is any Class 1, 2 or 5 weed for the land described in the Weed Control Order.

Other changes

There are a range of other changes which include:

- new requirements to ensure land owners provide details of occupiers to allow a Local Control Authority to issue written notice;
- changes to the method of publishing the declaration of a quarantine area;
- changes for emergency weed control order terms and their notification;
- an expansion in the range of emergency orders, actions and periods; and
- the notification of weeds on Lord Howe Island.

REFERENCE

NSW DPI, New South Wales Department of Primary Industries (2008). New South Wales Invasive Species Plan 2008-2015. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0020/236900/nsw-invasive-species-plan.pdf. (accessed 9 May 2013).

FURTHER INFORMATION

For further information or clarification of these changes, contact the relevant local Invasive Species Officer at the New South Wales Department of Primary Industries.
http://www.dpi.nsw.gov.au/agriculture/pests-weeds/weeds/contacts. (accessed 9 May 2013).

NEW ZEALAND HAWKWEED OVERVIEW AND CURRENT RESEARCH RESULTS

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SUMMARY

Hieracium was first reported in New Zealand in 1864. By 1992 *Hieracium* species occurred in over 6 million hectares, were common in 4.8 million hectares, conspicuous in 1 million ha, and dominant in half a million ha. Hawkweed invasion has resulted in ecosystem transformation in some locations. In a central eastern South Island site *H. pilosella* increased from 0.2% to 23.5% between 1990 and 2010. Bare ground increased by 19.2%. Indigenous fescue tussock decreased from 10% to 0.1% and species biodiversity decreased by 47%. These changes were not attributable to grazing management but to competitive exclusion. Environmental modelling indicates that large areas of mainland south- eastern Australia and Tasmania are potentially at risk from *Hieracium* invasion. As mainland Australian populations are at a very early stage of invasion, complete eradication should be attempted.

INTRODUCTION

Hawkweeds, *Hieracium* species, are globally serious rangeland weeds. Originating in the northern hemisphere these perennial herbs, members of the daisy family (Asteraceae), have invaded New Zealand, the United States, Canada, Japan, Patagonia and five species have been recorded in Australia (Williams and Holland 2007). Some species are highly invasive due to self-fertilisation and wind dispersed seed. Once established, rapid expansion can occur by stolons and rhizomes and the resulting dense populations out-compete other species, reducing pasture productivity and indigenous biodiversity (Boswell and Espie 1998).

Hieracium was first reported in New Zealand in 1864. The founder population, of *H. pilosella* L. (mouse-ear hawkweed) in Canterbury, was probably localised and slow to spread as it was not recorded again in subsequent accounts of naturalised flora until 1920. Orange hawkweed, *H. aurentiacuum* L., was the second species reported, in 1911 in North Canterbury. By 1920 *H. pilosella* was well established in localised mid-Canterbury pastures and small patches of *H. aurentiacuum* were also found but were eliminated by cultivation. Another species, *H. praealtum* Vill. ex Gochnat (king devil hawkweed), was profuse in the upper pastures of the mid- Canterbury plains and adjacent stream gorges. In the early 1960's an extensive survey of Canterbury tussock grasslands showed that *H. pilosella* and *H. praealtum* were widespread, well established, and occasionally very dense. Two further species, *H. lepidulum* (Stenstr.) Omang (tussock hawkweed) and *H. caespitosum* Dumort (field hawkweed) occur throughout the New Zealand high country, with localised areas of high abundance.

Nine *Hieracium* species and one hybrid are now naturalised in New Zealand (Webb et. al. 1988). Introduced by European colonisation in the mid nineteenth century, they now occur in over 6 million hectares and are dominant in 500 000 hectares (Hunter 1991). Two species, *Hieracium pilosella* and *H. praealtum* are now among the most abundant tussock grassland species in the moderate to low rainfall areas of the South Island high country.

The biology and ecology of *Hieracium* species in New Zealand has been reviewed by Espie 2001. This paper briefly outlines the invasion history in New Zealand and recent research results to assist with formulation of Australian preventative control strategies.

Methods

Information on early colonisation and spread was obtained from the literature.
Recent evidence relating to Hieracium invasion effects on vegetation trends is provided by a long-term study in the Mackenzie Basin, central eastern South Island.
Vegetation communities were assessed by field survey in 1984 during the Protected Natural Areas (PNA) survey of the Mackenzie Ecological Region (Espie et. al. 1994).
A long-term experiment was started in 1989 on the Pukaki Flat, a fluvioglacial outwash surface near Twizel in the centre of the Mackenzie basin, to investigate changes in composition of indigenous fescue tussock grasslands under different managements (Meurk et. al. 2002). Retirement from grazing was compared with grazing by rabbits and grazing by both rabbits and stock.

The grazing treatments were implemented using large 75 x 75 m fenced exclosures:

a) exclusion of rabbits and stock (coded –R-S)
b) rabbit grazing but no stock excluded (coded +R-S)
c) grazing by rabbits and stock, no exclosure (coded +R+S).

Since 1995 stock grazing on the Pukaki Flat has been restricted to occasional small groups of sheep for short periods and therefore grazing pressure has been negligible so that the differences between the +R-S and +R+S treatments are likely to be minimal.

To determine vegetation changes, every plant species present was recorded in eight randomly located permanently marked quadrats in a 20 x 20 m plot. To assist species location and percentage cover estimation, quadrats were subdivided into twenty five 10 x 10 cm grid squares for scoring. Plots were re-assessed eleven times between 1990 and November 2010. At each assessment every previously recorded species was individually searched for to accurately determine continuity or displacement. The size of individual fescue tussocks was measured ± 0.5 cm in randomly located circular plots of varying radius to include 50 tussocks.

Thin-plate spline modelling was used to estimate potential Hieracium distributions in Australia from New Zealand distributions.

RESULTS AND DISCUSSION.

Hieracium species expanded from a probable founder population in lowland Canterbury in the 1850's to over 6 million hectares by the 1990's (Figure 1).

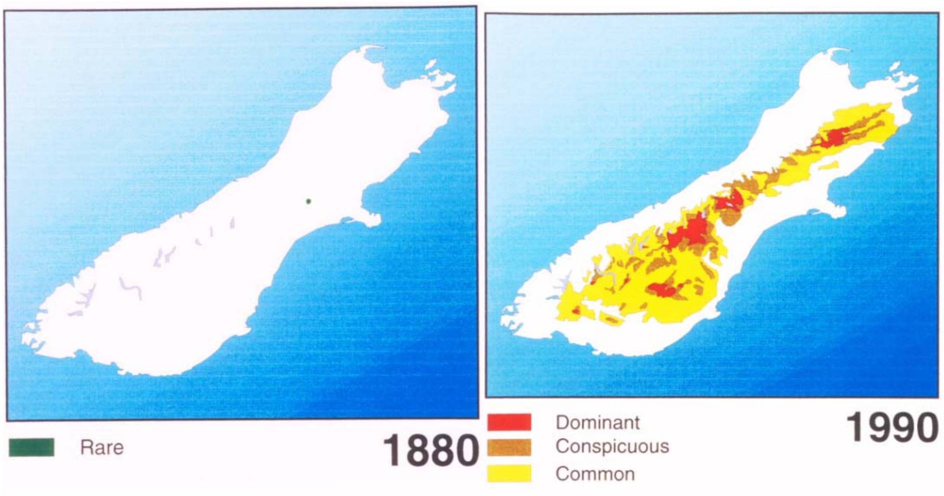

Figure 1. Hieracium expansion South Island 1880 – 1990. The Mackenzie Basin is included in the largest area of dominant cover, lower central region.

Detailed examination of *Hieracium* invasion at a representative site in the central Mackenzie basin showed mouse-ear hawkweed increased exponentially after 1992, irrespective of grazing management, peaked around 2000 and apparently stabilised at around 24 % cover by 2010 (Figure2).

Figure 2. Changes in *Hieracium pilosella* cover 1990 -2010.

Simultaneously bare ground increased (Figure 3) and cover of fescue tussock (*Festuca novae-zelandiae*) and the previously dominant herb, sheep's sorrel (*Rumex acetosella*) decreased (Figures 4, 5).

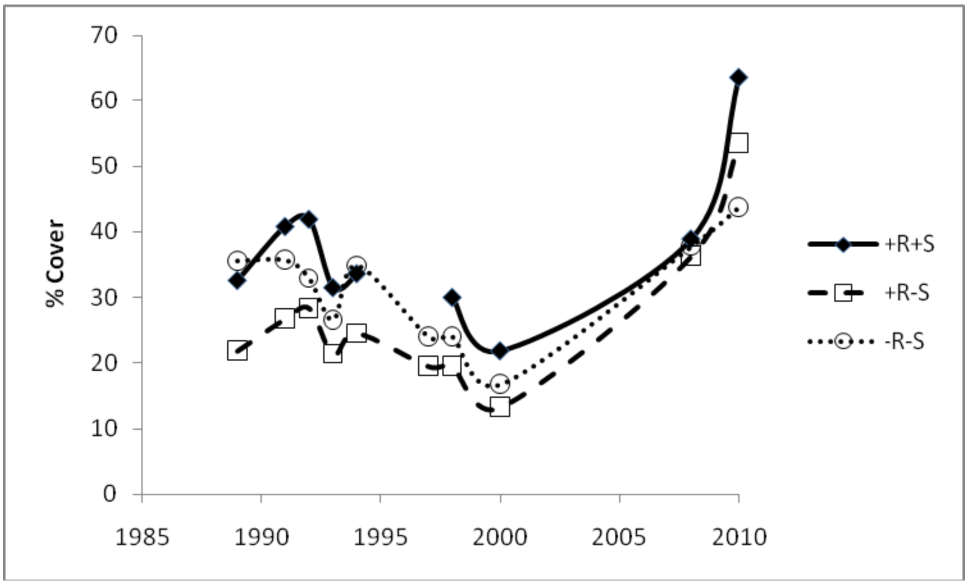

Figure 3. Changes in bare soil cover, 1990 -2010.

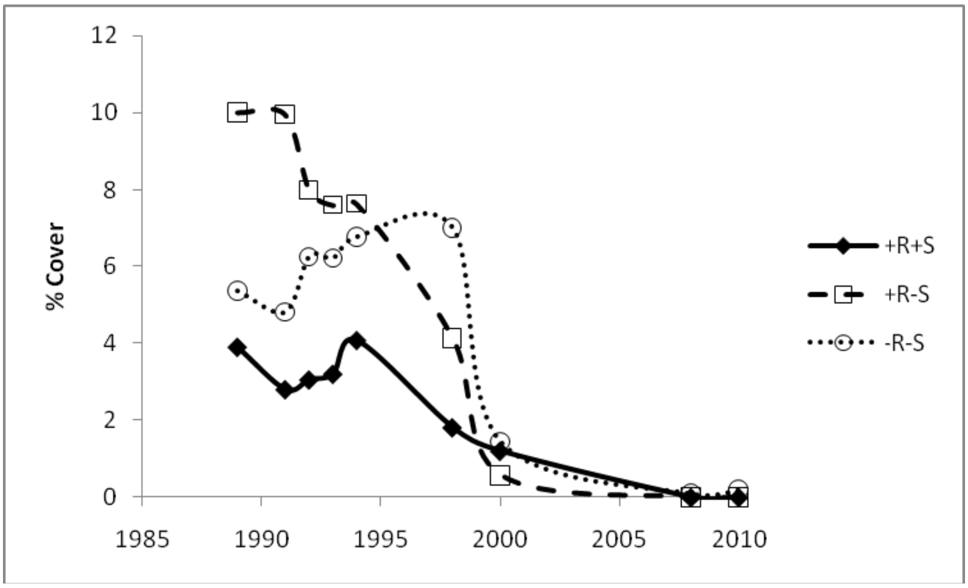

Figure 1. Changes in fescue tussock cover, 1990 -2010.

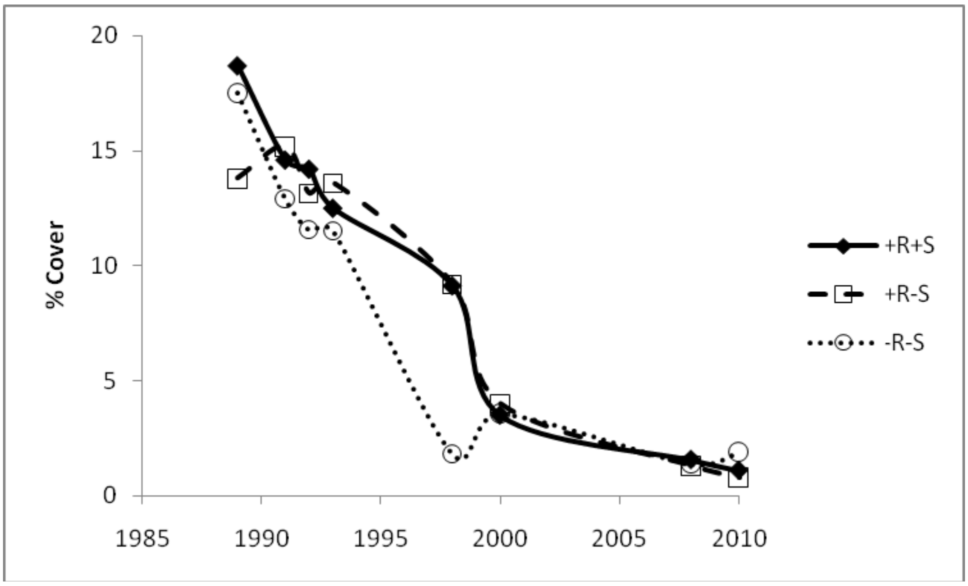

Figure 5. Changes in the dominant herb, sheep's sorrel, 1990 -2010.

Consistent with the cover trends, tussock size and density decreased between 2000 and 2010 irrespective of grazing (Figures 6, 7).

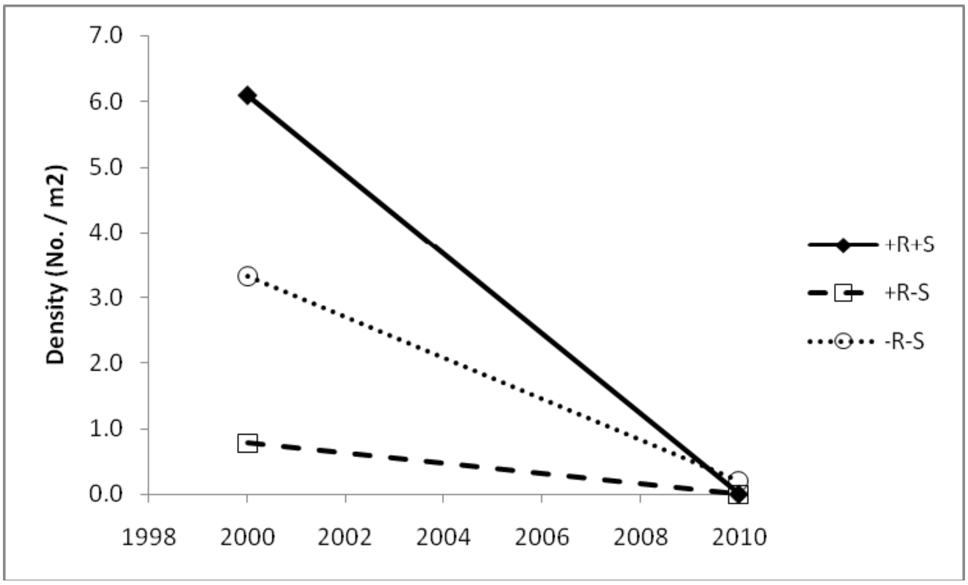

Figure 6. Change in Fescue tussock density 2000-2010.

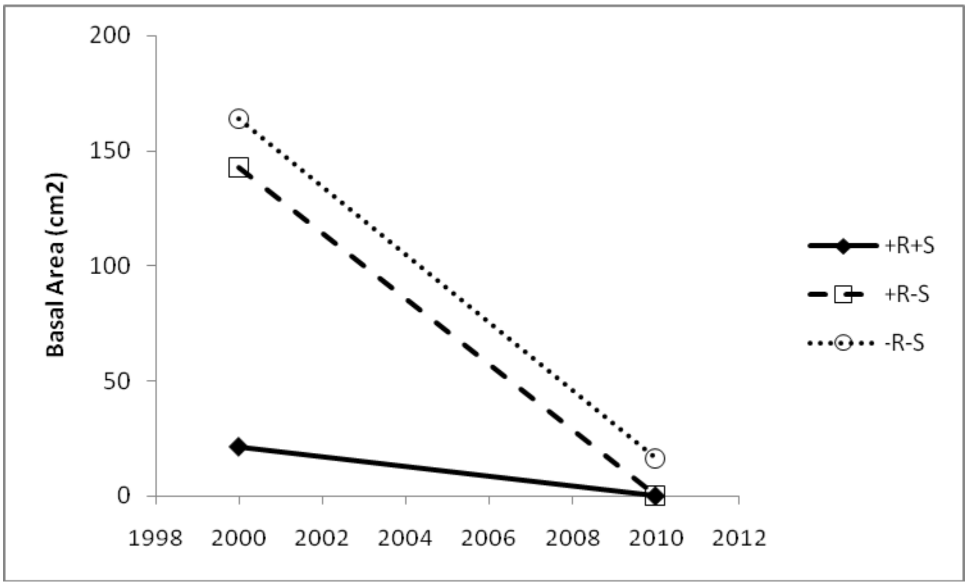

Figure 7. Change in Fescue tussock basal area 2000-2010.

Species biodiversity decreased by 47% between 1990 and 2010 (Figure 8).

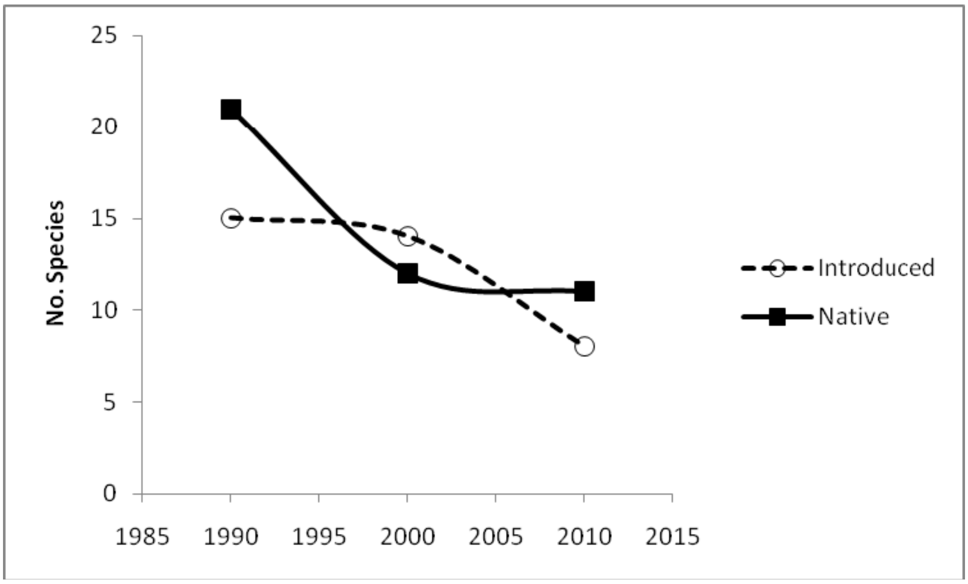

Figure 8. Changes in number of species, 1990 - 2010.

Climate modelling, using only a subset of New Zealand Hieracium occurrence records, indicates that Hawkweeds could potentially occupy large areas of mainland south- eastern Australia and Tasmania (Figure 9).

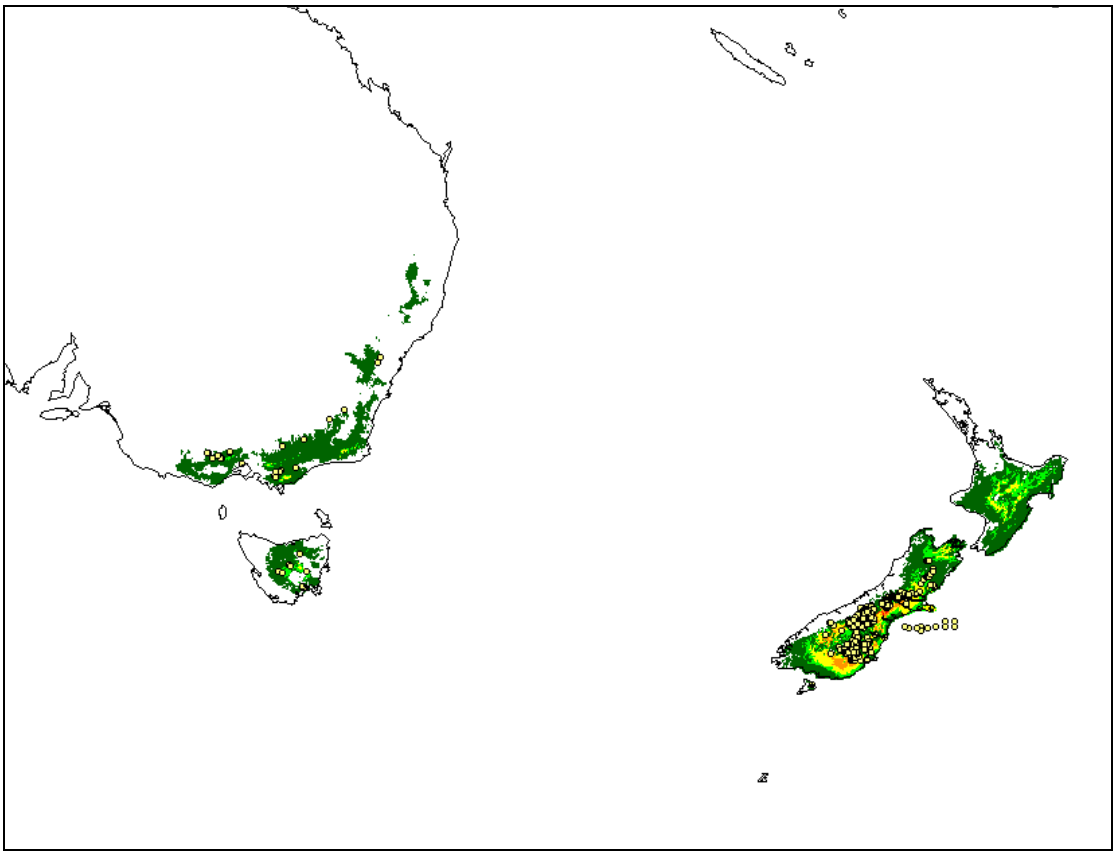

Figure 9. Potential areas at risk from Hieracium Invasion in Australia and New Zealand.

It is self-evident that Hieracium species pose an enormous threat to both Australian rangeland primary production and indigenous biodiversity.

Current naturalised incursions of *H. aurantiacum*, *H. praealtum*, *H. murorum* and *H. pilosella* have been identified and control procedures implemented (Williams and Holland 2007). As all known populations on mainland Australia are being controlled, or have been eliminated, it is critical that these sites and adjoining areas continue to be closely monitored to eliminate further recruitment and to identify undetected incursions. Prevention of future introductions is equally critical. As mainland Australian populations are at a very early stage of invasion, complete eradication is potentially feasible and should be attempted.

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