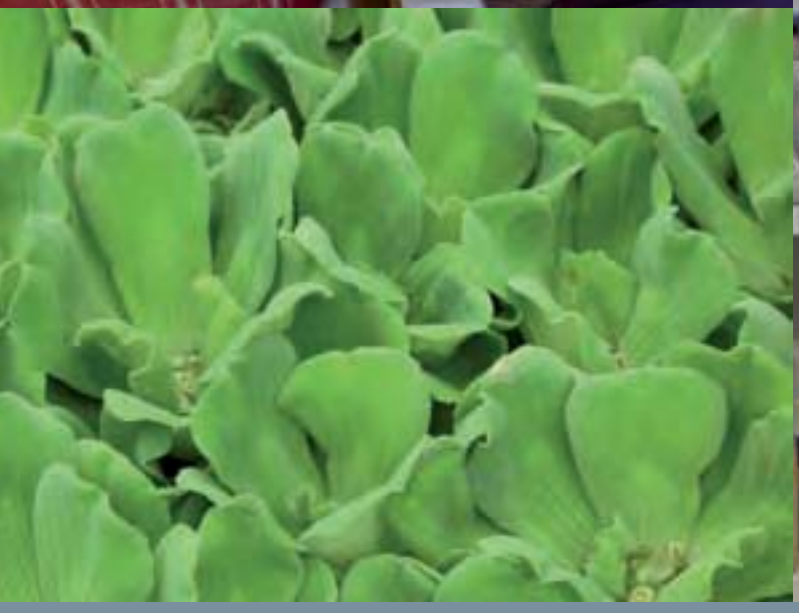
Department of **Employment, Economic Development and Innovation**

Technical highlights

Invasive plant and animal research 2009–10



Queensland Government

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Cover photos (clockwise from top left): Senior Zoologist David Berman radio-collaring a rabbit. The leaf-mining buprestid beetle (*Hylaeogena jureceki*) feeding on cat's claw creeper. Senior Scientist Lesley Ruddle preparing a sample for rodenticide analysis in the new laboratory facilities at the Health and Food Sciences Precinct. Water lettuce grown in controlled pond experiments at the Alan Fletcher Research Station.

Technical highlights

Invasive plant and animal research 2009–10

Contents

Executive summary

Achievements

In the past year, our team of scientists has continued to make significant progress in delivering innovative, quality research for improved management of Queensland's weeds and pest animals. Key achievements from our four research programs are outlined below.

Integrated weed management

New and improved management practices for the control of priority weeds continue to be developed and communicated to stakeholders. A manual—*Bellyache bush (*Jatropha gossypiifolia*) management manual: control options and management case studies from across Australia*—that provides comprehensive weed management information for landholders and weed managers has been published and distributed nationally. Copies are still available on request from the Tropical Weeds Research Centre (TWRC) for organisations that wish to increase awareness of bellyache bush and provide information on available control options during upcoming events.

We have received funding from Meat and Livestock Australia (MLA) to participate in a collaborative project on calotrope. We will work with Charles Darwin University and the Northern Territory Department of Natural Resources, Environment, The Arts and Sport (NRETAS) to improve our understanding of its spread, ecology, invasiveness and control.

Development of effective herbicide recommendations for problematic weeds has continued, with an increased focus on finding water-based options for treating weeds in sensitive areas, such as riparian habitats. Currently, we are testing stem injection applications on several woody weeds. Promising herbicides have been identified and rate refinement trials are now in progress.

In our biological control program, we have obtained official approval from Australian authorities and the Government of India to import three prioritised insects targeting prickly acacia into Australia from India for detailed host-specificity testing. Possibilities for biological control of bellyache bush remain limited, with a rust fungus the only agent still being considered. Several strains are undergoing testing overseas in an attempt to identify one that is host-specific.

Landscape protection and restoration

Three major environmental weeds of Queensland continue to be targeted by our biological control program. We are currently undertaking host-specificity testing of a leaf-mining buprestid beetle that attacks cat's claw creeper. Host-specificity testing of a leaf beetle targeting Madeira vine has been completed and formal application made for its release. Testing of a new pathogen against lantana continues in the United Kingdom (UK).

Research in support of Queensland's weed eradication programs continues to be a major focus of activity. Accelerated seed ageing trials conducted for Mexican feather grass and Mexican bean tree indicate that the seed bank of Mexican feather grass may be transient (persistence <1 year) and that of Mexican bean tree short-lived (persistence 1–3 years). Low volume, high concentration herbicide application though a splatter gun has proven very effective in controlling Siam weed in rugged terrain. Eradication field staff are now using this technology within the Townsville region in accord with a minor use permit issued by the Australian Pesticides and Veterinary Medicines Authority (APVMA).

In addition, we have conducted ecological research on Class 2 and Class 3 weeds. A major project on the impacts and control of three aquatic weeds (water hyacinth, water lettuce and salvinia) has been completed. Water hyacinth and water lettuce were associated with considerable increases in water loss through transpiration. Water hyacinth also frequently caused hypoxic (low oxygen) conditions and acidification of water. The three weeds showed variable responses to a number of herbicides, but effective products were found for each. Our experiments show that rapid destruction of plant infestations will temporarily increase nutrient concentrations, which could add to problems with algal blooms. Slower-acting herbicides may be preferable in suitable locations, since plants die back less rapidly, putting less stress on aquatic ecosystems. Population viability analysis studies on lantana have suggested that where populations are rapidly expanding, joint action involving at least 95% reduction in seed production, seed germination and seedling growth is required to stabilise the weed population growth rate.

Pest animal management

A new project investigating the ranging behaviour and effects on mesopredators and native wildlife of both maremma dogs guarding sheep and wild dogs living in adjoining areas has commenced near Hughenden in north Queensland. In this study we test whether maremmas do indeed offer the currently debated benefits of wild dogs through control of kangaroos and feral carnivores, but without the associated stock losses. The study will be replicated in central-western Queensland in 2011–12.

As part of a project by the Invasive Animals Cooperative Research Centre (CRC), we have undertaken field trials to support the registration of a bait containing a potential new toxin—para-aminopropiophenone (PAPP)—for wild dogs and foxes. The work has been time consuming, involving monitoring the survival of individual dogs and indices of abundance of wild dog and non-target wildlife populations in baited and unbaited areas in order to determine field efficacy and environmental side effects of the PAPP bait. The results, in conjunction with data from earlier pen trials undertaken at the Inglewood research station, are encouraging, but registration is at least 12 months away.

A Commonwealth-funded project to quantify the impacts of feral pigs on freshwater ecosystems in Cape York has been completed. The study found that feral pig activity had a negative impact on the ecological condition of ephemeral lagoons in Cape York, with the major impacts related to destruction of habitat and reduction in water clarity.

This study also demonstrated a positive association between pig abundance and the extent of impact.

Data on the distribution of rabbits from the web-based mapping tool RabbitScan has identified an expansion of rabbits into previously unoccupied areas in the last 5–10 years. This is most notable and concerning in the Darling Downs–Moreton Rabbit Board (DDMRB) area in south-eastern Queensland, where rabbits have been excluded for over 100 years. The results suggest there is a need for focussed control efforts in this area to prevent rabbits establishing.

Mice are a chronic problem to Queensland grain farmers, with plagues occurring every 3–4 years. The efficacy of six alternative rodenticides to the currently available zinc phosphide has now been assessed in laboratory and field enclosure trials. The work has supported a registration application for a pellet formulation of zinc phosphide. Of the other toxins, only a combined cholecalciferol and coumatetralyl bait showed promise, but will need further efficacy data to support future registration. An encouraging result for grain growers was that the currently used zinc phosphide bait can effectively reduce mice in a maturing, as opposed to an immature, wheat crop. We have also developed improved models for predicting autumn mouse abundance in Darling Downs grain crops, incorporating spring mouse abundance and autumn–winter rainfall of the previous year. The work has reaffirmed the need for local, farm-based monitoring of mouse abundance, rather than relying on monitoring potentially distant sites to provide an early warning of a mouse outbreak.

Research services

During 2009–10, our pest chemistry laboratory performed 164 toxicological investigations relating to the use of vertebrate pesticides and completed determinations of 1080 residues in baits for input into a model describing the degradation of 1080 baits in the environment. In addition, we have maintained the production of required amounts of 1080 solutions for use in Queensland's pest animal control programs and obtained or renewed 10 minor use herbicide permits.

Business report

A draft science action plan for Biosecurity in Queensland is being prepared. This high-level plan aims to provide guidance to Queensland's science providers, investors and other stakeholders on science direction, priorities, delivery and uptake over the next 3–5 years.

The research services team led by Senior Scientist Lesley Ruddle, which was previously based at Alan Fletcher Research Station (AFRS), relocated to new laboratories at the Health and Food Sciences Precinct at Coopers Plains in early May 2010. While benefiting from new cooperative opportunities with other Biosecurity Queensland chemistry staff at this new laboratory facility, the team will continue to deliver a range of pest management chemistry services for the Invasive Plants and Animals program. Completion of the Ecosciences Precinct at Boggo Road is progressing quickly and the remainder of staff at AFRS anticipates moving to these new facilities in late 2010.

As in previous years, our research program for 2009–10 was endorsed by the Research Review Committee—a group of senior scientific, operations and policy staff from Biosecurity Queensland. The committee critically reviews proposed project outcomes and allocated investments, and makes recommendations on strategic priorities, existing research gaps and projects due for scientific review. A detailed research and development plan for 2009–10 was again prepared and subsequently endorsed by the Land Protection Council.

A review of rabbit research was held at AFRS in March 2010. Internal and external panel members from Victoria and Western Australia reviewed existing knowledge, identified research gaps and set the direction for future rabbit research.

In the financial year 2009–10, Invasive Plant and Animal Science received total funding of $6.9 million. Government base funds amounted to $4.5 million, the Land Protection Fund provided $1.7 million and funding from research and development contracts with external partners totalled $0.65 million (see the table below).

There were no changes to the senior management and research team in 2009–10, except that Lesley Ruddle has now been appointed Senior Scientist and permanently replaced Bob Parker as leader of the Research Services program. In 2009–10, a total of 86 staff were engaged at our six research locations (see Appendix 2).

Collaboration and extension

We continue to be a core participant in the Invasive Animals CRC, working closely with pest animal experts from across Australia on a range of joint projects (e.g. rabbit resistance to rabbit haemorrhagic disease virus (RHDV) and the development of a new bait for wild dogs, foxes and cats). National collaboration and funding opportunities in weed research have been limited since the closure of the CRC for Australian Weed Management in 2008. A minor funding round ($2.5 million of an allocated $15.3 million) of the Australian Weeds Research Centre was delivered in 2009. However, the formation of a centre hosting collaborative projects has not occurred. Recently, the Rural Industries Research and Development Corporation was appointed by the Australian Government to deliver the 2010–2012 stage of the renamed National Weeds and Productivity Research Program, with up to $12.4 million available to fund research and administer the program until 30 June 2012.

We continue to build collaborative partnerships with a wide range of national and international research institutions; government agencies at the local, state and federal levels; regional natural resource management bodies; local community groups; industry associations and private businesses. Current key research collaborators in Australia include The University of Queensland (UQ), Queensland University of Technology (QUT), James Cook University, University of New England, CSIRO, Australian Centre for International Agricultural Research (ACIAR), Department of Environment and Resource Management

(DERM)/Queensland Parks and Wildlife Service (QPWS), Industry & Investment New South Wales and NRETAS, Northern Territory. We also maintain productive international partnerships with Agricultural Research Council – Plant Protection Research Institute (ARC-PPRI) in South Africa, Arid Forest Research Institute and Institute of Forest Genetics and Tree Breeding in India and CAB International (CABI) Europe–UK. Many of our research activities require field trials or sampling on the properties of private landholders. We greatly value their continued support.

Communication of results is an essential part of our research. Research results are communicated to scientific and land management professionals through publications and conferences. This year, our scientific staff authored or co-authored 26 peer-reviewed articles in international (18) and national (8) journals and published a comprehensive weed management manual on bellyache bush. Our scientists had significant involvement in the planning of the 10th Queensland Weed Symposium held in Yeppoon in July 2009 and provided 11 presentations or poster displays during the event. Extension activities were delivered to community and industry groups, landholders and land managers in the form of workshops, forums, lectures, seminars and public field days. All publications and extension activities from the past year are listed in appendixes 3 and 4.

The improvements made to the *Technical highlights* reporting format in last year's edition—links to our web pages as a source of further information and contact details included directly with each project report—were received favourably by our readers. We welcome any suggestions on how to further improve the presentation and delivery of our *Technical highlights* report in this year's client feedback survey. We also encourage all readers to visit the invasive plant and animal science pages on the Biosecurity Queensland website (www.biosecurity.qld.gov.au) as a source of further information. In addition, you can browse through our recent scientific publications in the fully-searchable eResearch Archive on the Department of Employment, Economic Development and Innovation (DEEDI) website at www.deedi.qld.gov.au (search 'eRA').

I am pleased to present *Technical highlights: Invasive plant and animal research 2009–10* to our clients, collaborators and colleagues. If you have any comments or require further information, please call me on (07) 3375 0739 or email gabrielle.viviansmith@deedi.qld.gov.au.

Dr Gabrielle Vivian-Smith

Principal Scientist
Invasive Plant and Animal Science
Biosecurity Queensland

External funding 2009–10

Research and development contracts

Project	Funding body	Funds ($)
Controlling calotrope in northern Australia	MLA	200 000
Biological control of prickly acacia	MLA	85 000
Biological control of Hudson pear	Industry & Investment New South Wales	80 000
Biological control of mikania vine in Papua New Guinea and Fiji	ACIAR	71 000
Mimosa pigra research	Reef Catchments	50 000
Livestock guardian dog/wild dog interaction study	DAFF	30 000
PAPP—a new toxin for managing wild dogs, foxes and feral cats	Invasive Animals CRC	23 000
Development of a cyanide bait for monitoring feral pigs and foxes	Invasive Animals CRC	12 000
Assessing feral pig damage to crops using remote sensing	DAFF	67 000
Feral pig impacts on freshwater ecosystems	DEWHA	20 000
Resistance to RHDV in Australian rabbits	Invasive Animals CRC	15 000
Effective and safe rodent management	Grains Research and Development Corporation	10 000
Total		**663 000**

Land Protection Fund

Project/ research area	Funds ($)
Understanding grader grass ecology for improved management	38 000
Bellyache bush bioevaluation	79 000
Seed dynamics	58 000
Biological control of bellyache bush	42 000
Biological control of prickly acacia	90 000
Biological control of mother-of-millions	80 000
Biological control of cat's claw creeper	126 000
Biological control of Madeira vine	138 000
Biological control of lantana	144 000
Rearing and release of weed biological control agents	183 000
Ecology and control of wet tropics weeds	44 000
Population viability analysis models for better management of lantana	42 000
Water weed management and control	134 000
Dry tropics feral pig research	90 000
Rabbit research	259 000
Pest management chemistry and chemical registration	143 000
Total	**1 690 000**

Part 1 Integrated weed management

1. Understanding grader grass (*Themeda quadrivalvis*) ecology for improved management

Project dates
July 2006 – June 2014

Project leader
Dr Wayne Vogler
Tropical Weeds Research Centre
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Other staff in 2009–10
Will Green and Laura Roden

Objectives
- Understand responses of grader grass to fire frequency and timing, and changes in pasture composition due to fire.
- Quantify seed longevity of grader grass.

Rationale
Management of invasive grasses has received little attention in comparison to research undertaken on other exotic weeds. There is a general lack of understanding of appropriate control options, particularly ones that are economical for application over large areas of low-value land and in areas of high conservation value.

Grader grass (*Themeda quadrivalvis*) has the potential to change biodiversity, reduce conservation values and reduce grazing animal production over large areas of the tropical savannas. It has been identified by DERM/QPWS as a critical conservation issue threatening biodiversity in national parks. It has also been identified in the pest management plans of several local governments as a significant threat both economically and environmentally, and by the Mitchell River Watershed Management Group as a significant weed species.

This project aims to explain some basic ecological aspects of grader grass in response to management and natural conditions, so that management recommendations are based on science rather than anecdotal evidence.

Photo 1. Grader grass plot fire in Undara National Park, May 2010.

Methods
Seed longevity
We sample soil seed banks at least annually in areas where seed input has been stopped. We also estimate seedling emergence in these areas to determine what proportion of the seed bank has emerged and what proportion has decayed. We establish artificial seed banks by burying seed in mesh bags, then recover these bags at various intervals and test seed viability by germination and use of standard tetrazolium testing procedures.

Effect of fire frequency and timing
In this trial we examine the effect of fire frequency and timing on grader grass biomass and overall pasture composition. This is a replicated plot trial where we impose each of the treatments (fire during dry season, fire at start of wet season, fire at end of wet season) at annual, two-yearly and four-yearly intervals. For comparison, we also apply the herbicide paraquat at a concentration of 250 g L^{-1} prior to seed set at annual intervals. Changes in pasture species and biomass composition are measured using the Botanal methodology.

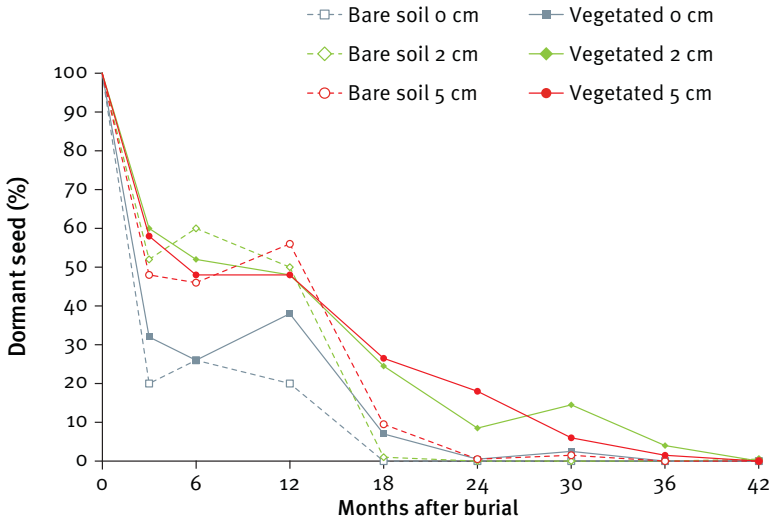

Figure 1. Grader grass seed decline in artificial seed banks established in November 2006 in bare and vegetated plots at 0 cm, 2 cm and 5 cm depths.

Progress in 2009–10

Seed longevity

Observed patterns of grader grass dormant seed decline (Figure 1) suggest that the principal driver of seed bank decline is germination following significant rainfall events. Following four wet seasons (42 months after burial), the viability of surface-situated and buried seed—regardless of cover—has declined to zero. This indicates that seed production needs to be prevented for four years in order to achieve eradication of grader grass. Where eradication is not feasible (e.g. in the tropical savannas of northern Queensland), seed production should be minimised by limiting disturbance (maintaining grass cover and minimising fire).

Effect of fire frequency and timing

Grader grass biomass was generally maintained in annual and biennial fire treatments applied at any time of year (Figures 2 and 3), except for the biennial late wet treatment in 2009, where biomass was similar to that of the control treatment (Figure 3). It is unclear at this stage why this reduction in grader grass biomass occurred, but it may be caused by the previous late wet fire (applied in 2008) killing a large proportion of the grader grass seed. In contrast, where disturbance was minimal (such as in the control and herbicide treatments), grader grass biomass continued to be much lower following the fourth year of treatment.

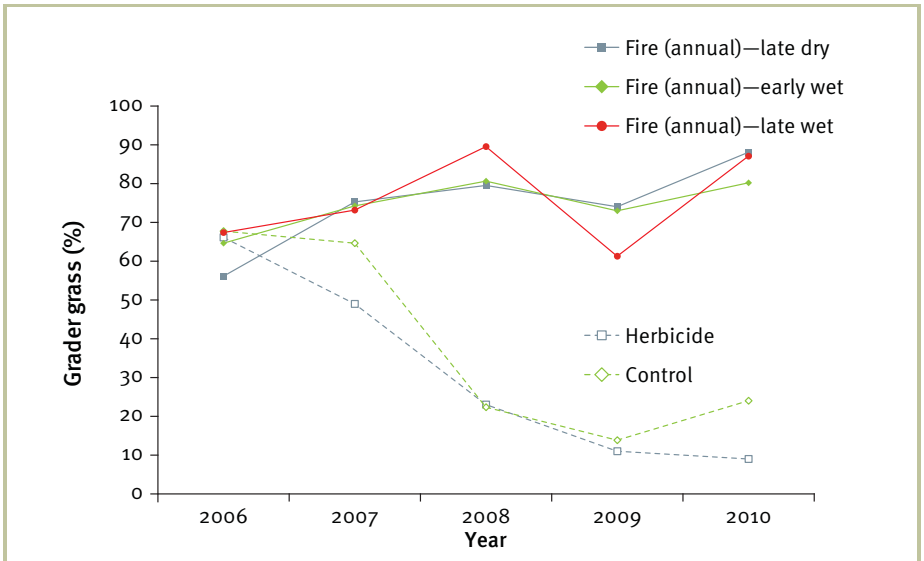

Figure 2. Grader grass response to fires implemented annually at Undara National Park.

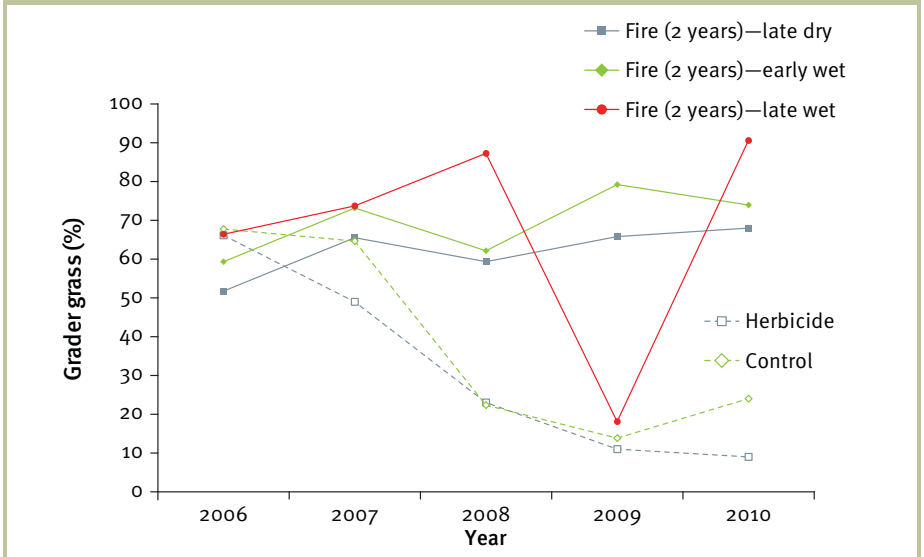

Figure 3. Grader grass response to fires implemented every two years at Undara National Park.

Where fire has been excluded for four years following treatment, grader grass biomass has declined to levels similar to those of the control and herbicide treatments (Figure 4). These results continue to confirm that grader grass invasion and dominance is inherently related to the frequency of fire disturbance within a pasture system. They suggest that using fire periodically (minimum four year interval) for weed or pasture management purposes may maintain grader grass biomass at manageable levels if other disturbances are limited. They also suggest that managing to minimise disturbance is a critical factor in reducing the presence and impact of this invasive grass.

Funding in 2009–10

- Queensland Government
- Land Protection Fund ($38 000)

Collaborators

- DERM/QPWS, Undara National Park
- Northern Gulf Resource Management Group
- Southern Gulf Catchments
- Landholders

More information

Key publications

Vogler, W. 2009. *Grader grass management guide*. Burdekin Dry Tropics Natural Resource Management, Northern Gulf Resource Management Group, Southern Gulf Catchments. 8 pp.

Vogler, W.D. and & Owen, N.A. 2008. Grader grass (*Themeda quadrivalvis*): changing savannah ecosystems. In: *Proceedings of the 16th Australian Weeds Conference*. R.D. van Klinken, V.A. Osten, F.D. Panetta and J.C. Scanlan, eds. Queensland Weeds Society, Brisbane. p. 213.

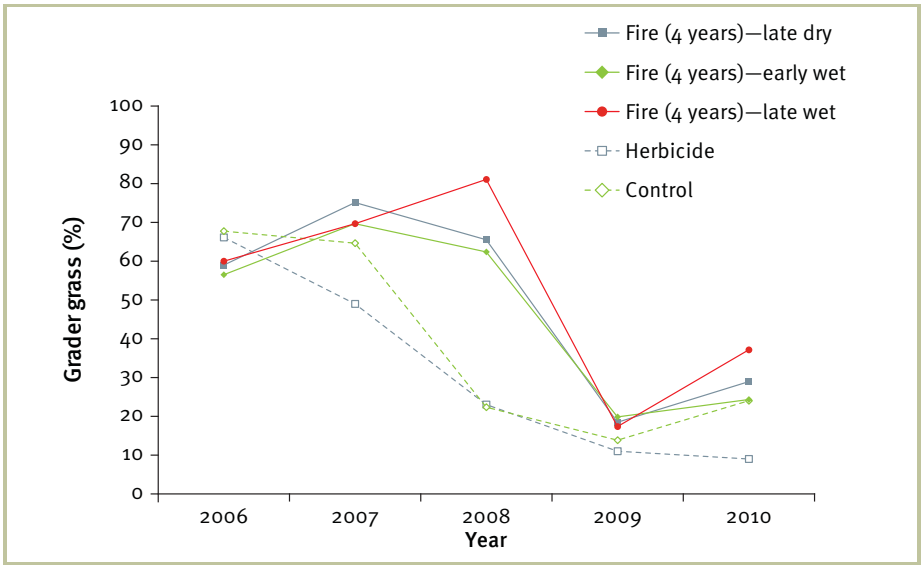

Figure 4. Grader grass response to fires implemented every four years at Undara National Park.

Keir, A.F. and Vogler, W.D. 2006. A review of current knowledge of the weedy species *Themeda quadrivalvis* (grader grass). *Tropical Grasslands* 40(4): 193–201.

For further information on this research project and access to key publications, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

2. Integrated management of bellyache bush (*Jatropha gossypiifolia*) in northern Queensland

Project dates
July 2000 – June 2011

Project leader
Dr Faiz Bebawi
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Other staff in 2009–10
Shane Campbell and Chris Crowley

Objectives
- Develop an integrated management strategy for bellyache bush.
- Evaluate the efficacy of combinations of fire, slashing and foliar herbicides on mortality, seedling recruitment and survival of bellyache bush.
- Better understand the ecology of bellyache bush and its implications for timing and effectiveness of control strategies.
- Promote changes in management practices that will lead to sustainable levels of production.

Rationale
Bellyache bush (*Jatropha gossypiifolia*), a native of tropical America, is a major weed of the Burdekin and Palmer River catchments in Queensland. It is also starting to spread in the Fitzroy catchment and other areas of central and northern Queensland. Dense infestations generally form along river flats, creek banks and disturbed roadsides.

This project helps to fill knowledge gaps about bellyache bush seed ecology, competitive ability under different simulated grazing pressures, population dynamics and the impact of integrated control techniques in order to develop best practice management strategies.

Methods
There are two areas of research associated with this project—integrated weed control and weed ecology of bellyache bush.

Integrated weed control
We trial individual and integrated control techniques to determine the most effective combination of burning, slashing, stick-raking and chemical treatments for controlling bellyache bush.

Weed ecology
Seed longevity (initiated in March 2001): We bury two types of bellyache bush seeds (intact and ant-discarded) at six depths (0 cm on mulched ground, 0 cm on bare ground, 5 cm, 10 cm, 20 cm and 40 cm) under natural and rain-shelter conditions.

Pasture management research (initiated in September 2002): In a competition trial we determine the impact of five simulated grazing regimes—no grazing (uncut pasture), low grazing (cut at 40 cm height), medium grazing (cut at 20 cm height), high grazing (cut at 10 cm height) and no pasture (pasture removed)—on four bellyache bush densities—control (no bellyache bush), low density (2 plants m^{-2}), medium density (6 plants m^{-2}) and high density (12 plants m^{-2}).

Progress in 2009–10
Integrated weed control
Field trials were completed in June 2006. For final results see *Technical highlights 2005–06*. A scientific paper on the results has now been submitted for publication in *The Rangeland Journal*.

Weed ecology
Seed longevity: Under natural conditions, intact seeds exhumed have all expired after 36 months, compared with 72 months for ant-discarded seeds (Figure 1). At the rainfall-excluded site, all intact seeds expired 84 months after burial. However, ant-discarded seeds showed some signs of viability (average 1%) 108 months after burial, particularly at the 5 cm depth. As there is still a small quantity of viable seed remaining, the final lot of samples will be tested in 2011.

Pasture management research: Under the simulated grazing conditions of this trial, pasture yield over all grazing regimes has been 19% lower in 2009–10 compared with yield in 2008–09. However, consistent with results from last year, pasture yield was greater (though not significantly so) in high grazing plots compared with those subjected to low grazing (Figure 2), irrespective of the density of bellyache bush.

After eight years, only 19% mortality has occurred in areas devoid of pasture (i.e. pasture removed), despite a four-fold

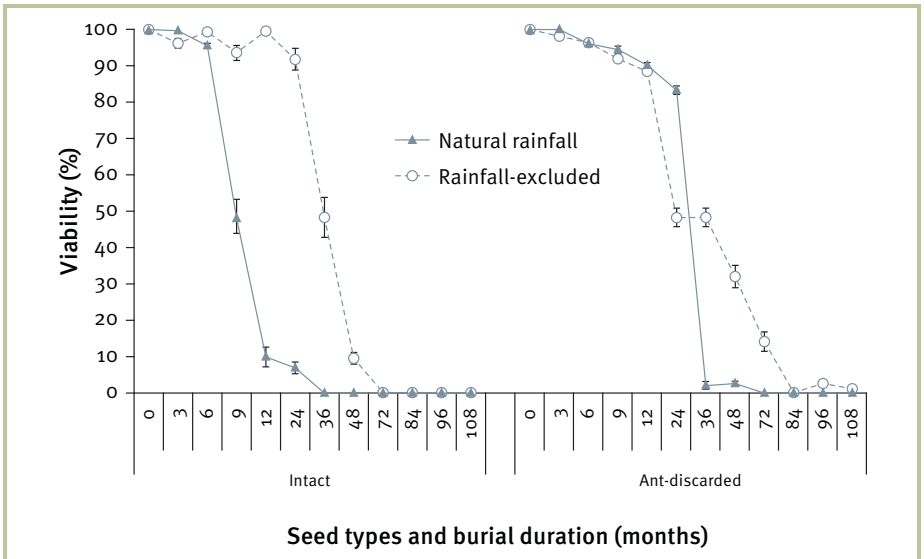

Figure 1. Viability of intact and ant-discarded seeds over 108 months in natural and rainfall-excluded sites, averaged over all burial depths.

increase in mortality from last year. In contrast, mortality has ranged from 68% in the no grazing plots to 74% under low grazing (Figure 3). Over all bellyache bush densities, mortality was greater by 7% after 8 years, compared with that from last year. The trial is ongoing.

Funding in 2009–10

Queensland Government

Collaborators

Ralph Woodard (Branmore Station)

More information

Key publications

Grice, A.C., Campbell, S.D., Breaden, R., Bebawi, F.F. and Vogler, W.D. 2008. *Habitat management guide – rangelands: ecological principles for the strategic management of weeds in rangeland habitats*. CRC for Australian Weed Management, Adelaide. 33 pp.

Bebawi, F.F., Vitelli, J.S., Campbell, S.D., Vogler, W.D., Lockett, C.J., Grace, B.S., Lukitsch, B. and Heard, T.A. 2007. The biology of Australian weeds 47. *Jatropha gossypiifolia* L. *Plant Protection Quarterly* 22(2): 42–58.

Bebawi, F.F., Lockett, C.J., Davis, K.M. and Lukitsch, B.V. 2007. Damage potential of an introduced biological control agent *Agonosoma trilineatum* (F.) on bellyache bush (*Jatropha gossypiifolia* L.). *Biological Control* 41(3): 415–422.

Bebawi, F.F., Cooper, A.P., Brodie, G.I., Madigan, B.A., Vitelli, J.S., Worsley, K.J. and Davis, K.M. 2007. Effect of microwave radiation on seed mortality of rubber vine (*Cryptostegia grandiflora* R.Br.), parthenium (*Parthenium hysterophorous* L.) and bellyache bush (*Jatropha gossypiifolia* L.). *Plant Protection Quarterly* 22(4): 136–142.

Bebawi, F.F., Mayer, R.J. and Campbell, S.D. 2005. Flowering and capsule production of bellyache bush (*Jatropha gossypiifolia* L.). *Plant Protection Quarterly* 20(4): 129–132.

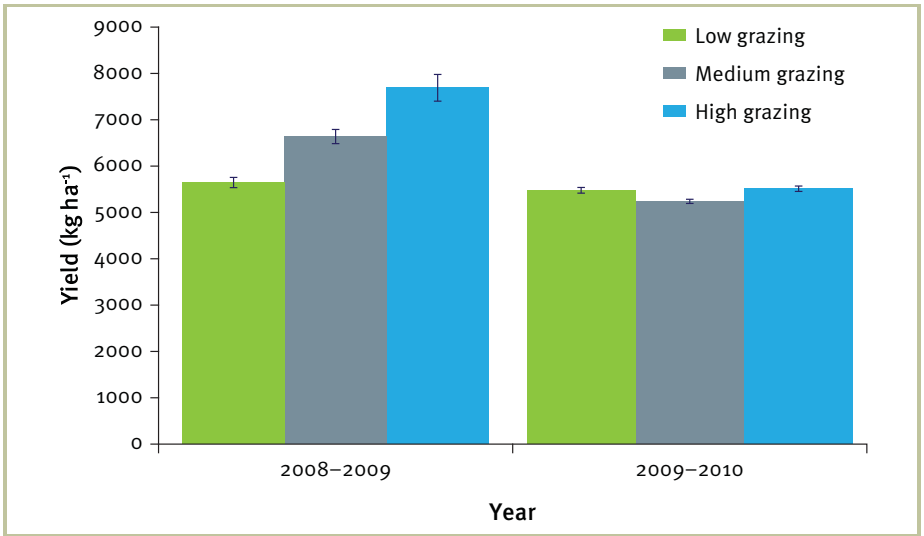

Figure 2. Pasture yield as affected by different simulated grazing regimes. (Vertical bars indicate the standard error (SE) of the means.)

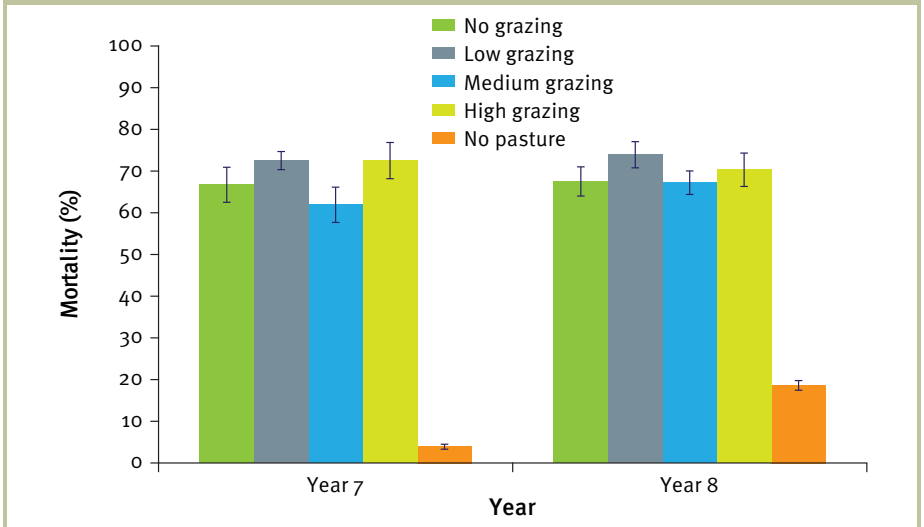

Figure 3. Mortality of bellyache bush plants subjected to five simulated grazing regimes, in the seventh and eighth year of treatment. (Vertical bars indicate the SE of the means.)

Bebawi, F.F., Mayer, R.J. and Campbell, S.D. 2005. Phenology of bellyache bush (*Jatropha gossypiifolia* L.) in northern Queensland. *Plant Protection Quarterly* 20(2): 46–51.

Bebawi, F.F. and Campbell, S.D. 2004. Interactions between meat ants (*Iridomyrmex spadius*) and bellyache bush (*Jatropha gossypiifolia*). *Australian Journal of Experimental Agriculture* 44(12): 1157–1164.

Bebawi, F.F. and Campbell, SD. 2002. Effects of fire on germination and viability of bellyache bush (*Jatropha gossypiifolia*) seeds. *Australian Journal of Experimental Agriculture* 42(8): 1063–1069.

Bebawi, F.F. and Campbell, S.D. 2002. Impact of fire on bellyache bush (*Jatropha gossypiifolia*) plant mortality and seedling recruitment. *Tropical Grasslands* 36(3): 129–137.

Bebawi, F.F. and Campbell, S.D. 2002. The response of bellyache bush (*Jatropha gossypiifolia*) plants cut off at different heights and seasonal times. *Tropical Grasslands* 36(2): 65–68.

For further information on this research project and access to key publications, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

3. Bellyache bush (*Jatropha gossypiifolia*) national management manual

Project dates

February 2009 – January 2010
(completed)

Project leader

Dr Shane Campbell
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Other staff in 2009–10

Anita Randall, Wayne Vogler, Faiz Bebawi and Barbara Madigan

Objective

Convert seven years of scientific research and the experiences of land managers into a practical manual for use by anyone involved in management of bellyache bush.

Rationale

Bellyache bush (*Jatropha gossypiifolia*) is one of the major weeds threatening the dry tropics of northern Australia. It forms dense thickets, takes over productive pastoral land and reduces biodiversity.

Extensive collaborative research into its ecology and control was undertaken over a seven-year period through the CRC for Australian Weed Management. While several scientific publications were produced from this research, it is critical that this information is converted into layperson's terms and made available to the broader community, particularly those currently involved in management of bellyache bush. It is also important to share the experiences of land managers who have been controlling this weed, as their experiences can prove invaluable to anyone commencing a control program.

Methods

All available research literature is collated and an experienced writer converts this scientific information into a practical technical section. A series of case studies is also developed by identifying, visiting and interviewing land managers across northern Australia. The case studies aim to demonstrate the array of control options available, as well as management at different scales, from individual properties to large community-based activities involving numerous landholders. Once a full draft of the manual is compiled it is circulated to key stakeholders for review and refinement. A distribution plan is developed to ensure that all key stakeholders receive the publication.

Progress in 2009–10

The manual has been published, with 4000 copies printed. Several thousand copies have now been distributed throughout Queensland, the Northern Territory and Western Australia. Copies are still available on request for organisations that wish to increase awareness of bellyache bush and provide information to land managers on available control options during upcoming events.

Funding in 2009–10

- Queensland Government
- Department of Agriculture, Fisheries and Forestry (DAFF)

Collaborators

- CSIRO
- Department of Agriculture and Food, Western Australia
- NRETAS, Northern Territory

More information

Key publications

Randall, A., Campbell, S., Vogler, W., Bebawi, F. and Madigan, B. 2009. *Bellyache bush (Jatropha gossypiifolia) management manual: control options and management case studies from across Australia*. The State of Queensland, Department of Employment, Economic Development and Innovation, Brisbane. 104 pp.

For further information on bellyache bush research, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

Photo 1. Front cover of *Bellyache bush (*Jatropha gossypiifolia*) management manual: control options and management case studies from across Australia*.

4. Ecology of Captain Cook tree (*Cascabella thevetia*) in northern Queensland

Project dates
July 2007 – June 2012

Project leader
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Other staff in 2009–10
Chris Crowley

Objective
Better understand the ecology of Captain Cook tree and the implications for timing and effectiveness of control strategies.

Rationale
Captain Cook tree (*Cascabella thevetia*) is a Class 3 declared weed in Queensland (a garden escapee) that has established some relatively large infestations in northern Queensland, particularly along riverbanks of the Douglas River and major creeks of the lower and upper Burdekin catchment near Mingela and Ravenswood. Captain Cook tree is toxic to humans and animals and dense infestations out-compete native pastures and reduce plant and animal biodiversity, as well as pasture productivity. It will continue to spread throughout its current range unless controlled. Understanding the ecology of Captain Cook tree is essential to developing effective management strategies and reducing its economic, environmental and social impacts.

Methods
There are six experiments.

Experiment 1 (initiated in Sep. 2007)
We determine the effects of monthly ambient temperatures on germination of both peach- and yellow-flowering plants at TWRC. The experiment uses a 2 × 12 factorial replicated four times using a split-plot design. Factor A is flowering type (peach and yellow) and factor B is sowing period (January to December). We sow 50 freshly harvested seeds per replicate at the beginning of each month for 12 months in 40 cm diameter plastic pots filled with river loam soil. Soil is maintained at field capacity. Initial germinability and viability are determined from sub-samples of the seed pool prior to sowing. We remove germinated seeds from the pots as they emerge, with ungerminated seeds exhumed after 8 weeks from sowing and tested for viability using a tetrazolium test. The study is repeated several times to quantify the effect of different seasonal conditions.

Experiment 2 (initiated in Dec. 2007)
We determine the age to reproductive maturity of both peach- and yellow-flowering plants under different light and plant density conditions at TWRC. The experiment uses a 2 × 4 × 2 factorial replicated four times using a split-split plot design. Factor A comprises light regime (natural light and 70% shade) assigned to the main plots, factor B is planting density (1, 2, 4 and 8 plants per pot) assigned to the sub-plots, and factor C is flowering type (peach and yellow) assigned to the sub-sub-plots. We grow plants from seed in plastic pots (50 cm diameter × 40 cm depth) filled with river loam soil and monitor growth rate (basal diameter and plant height), age to reproductive maturity, flowering density (number of flowering stalks) and seed production.

Experiment 3 (initiated in Jan. 2008)
We determine growth, seedling survival and age to reproductive maturity of peach-flowering plants growing in the field at Will Creek, Mingela, under either full shade or natural light. The experiment uses a completely randomised design with six replications. For the light treatment we cut-stump dense infestations of established Captain Cook tree plants. Cut-stumping involves cutting plants at 5 cm height with a brush cutter and then immediately applying herbicide to the cut surface. The control treatment (shade treatment) is left uncut so that a fully closed canopy is present above the seedlings. We tag 25 seedlings (with cotyledons still attached to the hypocotyl) emerging after the first rainfall event in each plot and monitor their growth rate (basal diameter and plant height), survival rate and age to reproductive maturity.

Experiment 4 (initiated in Jan. 2008)
We monitor seed production and seed predation of peach-flowering plants growing under natural conditions at Will Creek, Mingela. We establish six permanent

Photo 1. Dr Gabrielle Vivian-Smith (Principal Scientist, Invasive Plant and Animal Science, Biosecurity Queensland) inspecting seed traps under Captain Cook trees.

quadrats (approx. 5.3 m^2 ± 0.3 m^2) beneath the canopy of Captain Cook trees and collect intact and cracked seeds, twigs and litter at monthly intervals. For each sample, we count seeds and twigs and calculate the dry weight of litter.

Experiment 5 (initiated in Jun. 2008)

This study comprises two sub-experiments. Sub-experiment 5a is comparing germination of peach- and yellow-flowering plants under a range of alternate (day/night, 12/12 hr) temperature regimes, and sub-experiment 5b is comparing their germination under a range of constant temperature regimes. Both sub-experiments use a 10 × 2 factorial replicated four times using a split-split plot design. Factor A is temperature gradient assigned to the main plots and factor B is flowering type (peach and yellow) assigned to the sub-plots. We place lots of 50 freshly harvested seeds in 500 mL plastic containers with lids (15 cm × 10 cm × 3.4 cm) filled to 1 cm depth with distilled water. Four trays of each flowering type are placed in each of 10 temperature compartments of a thermogradient incubator. A temperature range of 11.4 °C to 2.5 °C during the day and 6.1 °C to 40 °C during the night is allocated to sub-experiment 5a and a constant temperature range of 13.6 °C to 49.2 °C is allocated to sub-experiment 5b. We count and remove germinated seeds from each tray on a daily basis and then re-randomise the position of trays within each chamber to minimise heat exposure bias. Germination is considered to have ceased when no seeds germinate for two weeks after the last recorded germination. We then test ungerminated seeds for viability.

Photo 2. Dr Faiz Bebawi inspecting a sap flow sensor installed on a Captain Cook tree.

Experiment 6 (initiated in Aug. 2009)

We detail sap flow velocity and water use efficiency of three size classes (60–90 mm, 91–130 mm and 131–230 mm basal stem diameter) of Captain Cook trees (peach-flowering type) growing under natural conditions at Will Creek, Mingela. We establish sap flow sensors on 15 plants, including two natives (eucalypt and black tea tree), to collect data on sap flow velocity and volume of water transpired on an hourly daily basis. Data is downloaded at monthly intervals from a Smart Logger. Processed data will provide information on the periodicity of physiological activity of Captain Cook trees, which will be used to refine the timing of control activities to maximise mortality.

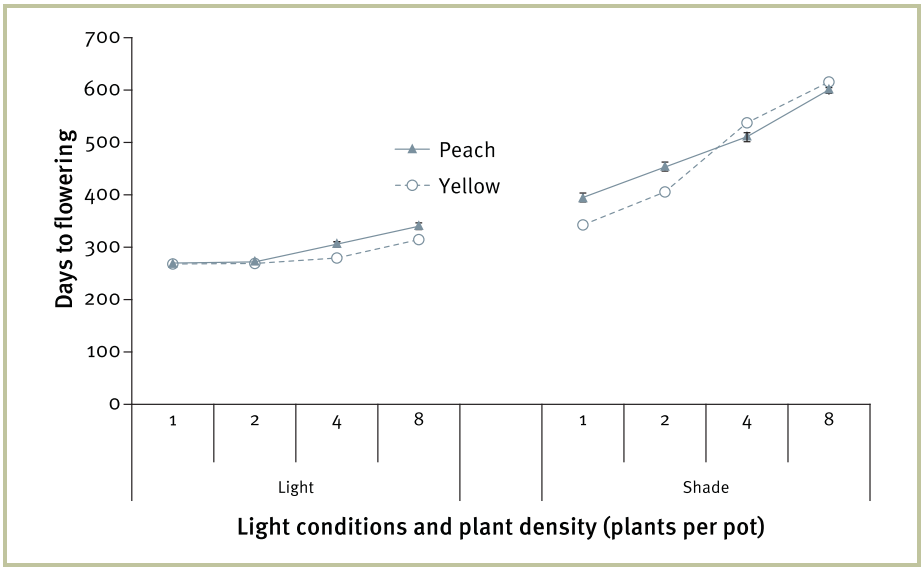

Figure 1. Days to flowering of peach- and yellow-flowering plants growing at different plant densities and under natural light or shaded conditions. (Vertical bars indicate the SE of the means.)

Progress in 2009–10

Experiment 1

This experiment is completed and currently being analysed. For preliminary results see *Technical highlights 2008–09*.

Experiment 2

Under natural light conditions, peach- and yellow-flowering plants took similar times to reach reproductive maturity (on average 268 days) at the two lowest plant densities (one and two plants per pot). As plant density increased, the peach-flowering plants tended to take longer to mature. A combination of shading and plant density caused the greatest delays in reaching reproductive maturity for both peach- and yellow-flowering plants. On average, plants took 620 days to flowering when grown at the highest plant density under shaded conditions (Figure 1).

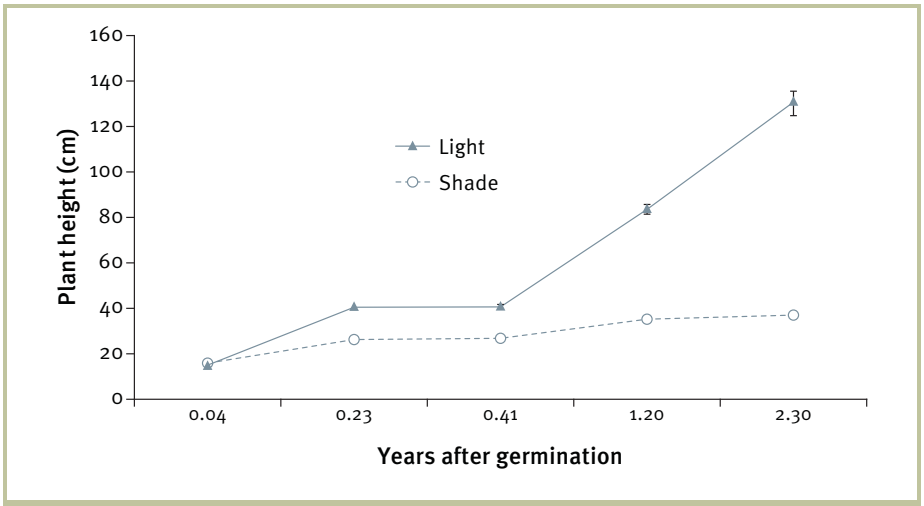

Figure 2. Plant height of peach-flowering plants as affected by light conditions at Mingela. (Vertical bars indicate the SE of the means.)

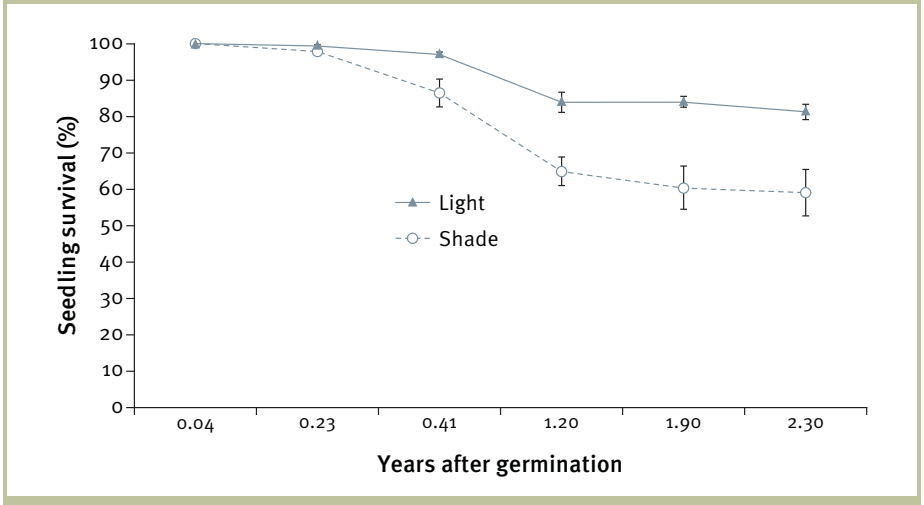

Figure 3. Seedling survival of peach-flowering plants as affected by light conditions at Mingela. (Vertical bars indicate the SE of the means.)

Other key findings were reported in *Technical highlights 2008–09*.

Experiment 3

28 months after germination, plant height was nine-fold greater than the initial height under light, compared with a two-fold increase under shade (Figure 2). Similarly, basal diameter was seven-fold greater under natural light compared with two-fold greater under shade. Seedling survival was significantly greater under light conditions (81%) compared with shade conditions (59%) (Figure 3). The experiment is ongoing.

Experiment 4

For results relating to seed predation see *Technical highlights 2008–09*.

Whilst twigging of Captain Cook tree branches by wildlife occurred all year, both twigging and litter production (natural leaf drop) peaked during autumn (April). Twigging also reached a lesser peak during spring (October), but litter production declined significantly throughout winter, spring and early summer (Figure 4). There were highly positive correlations between seed predation and twigging (R^2 = 0.96) and between seed production and twigging (R^2 = 0.95). There was also a strong positive correlation between seed predation and litter production (R^2 = 0.72) and between seed production and litter production (R^2 = 0.71). Furthermore, a strong positive correlation existed between twigging and litter production (R^2 = 0.71). This experiment is completed.

Experiment 5

This experiment is completed. For key results see *Technical highlights 2008–09*.

Experiment 6

An example of the data collected through the sap flow sensors is shown in Figure 5. During February 2010, the total volume of water used by Captain Cook trees averaged 93.7 L. The graph also shows considerable variation in sap flow velocity over time, which could influence the efficacy of control techniques such as herbicide applications. This experiment is ongoing.

Funding in 2009–10

Queensland Government

Collaborators

- John Ramsey, Landholder (Meadow Vale Cattle Station, Mingela)
- Bob J. Mayer, Senior Biometrician (DEEDI, Oonoonba)
- Carole Wright, Biometrician (DEEDI, Oonoonba)

More information

For further information on this research project, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

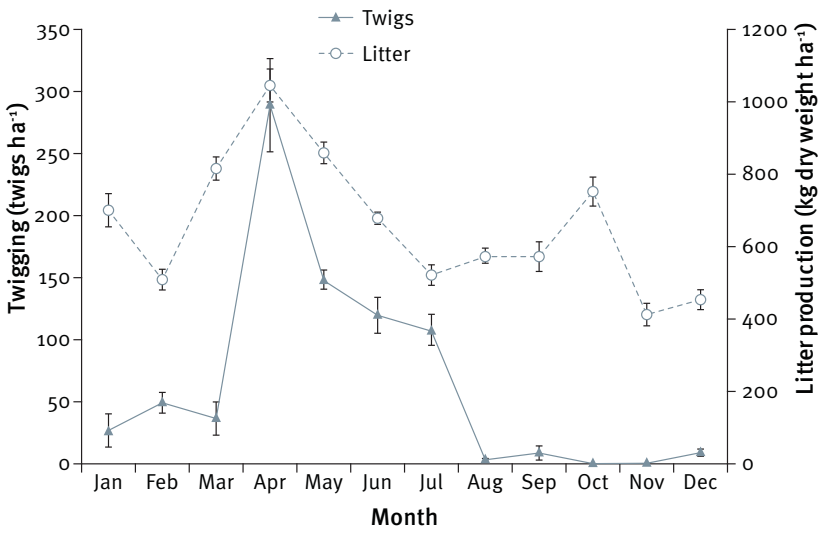

Figure 4. Twigging and litter production of peach-flowering plants at Mingela. (Vertical bars indicate the SE of the means.)

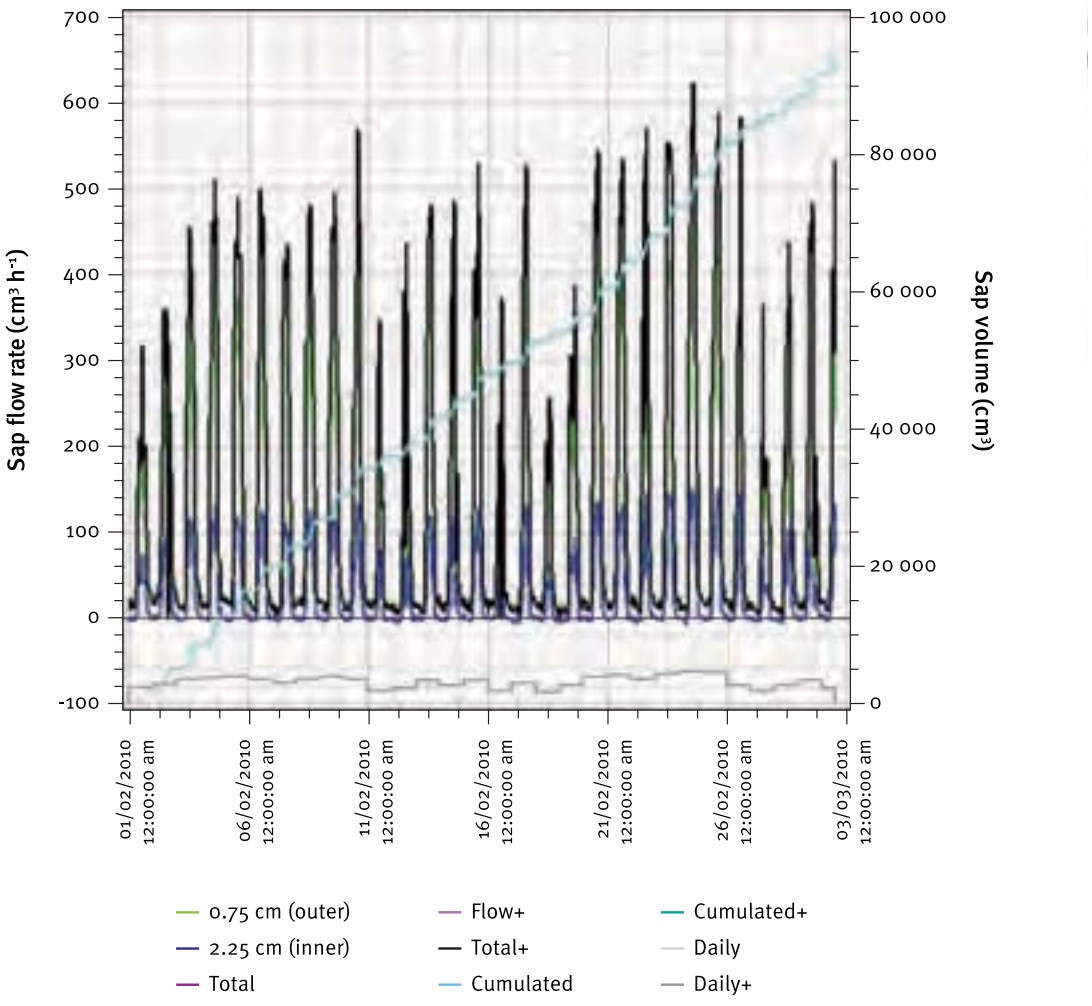

Figure 5. Hourly sap flow rate and sap volume of Captain Cook tree for the month of February 2010. Aqua blue line indicates the cumulated flow rate.

5. Seed dynamics

Project dates
August 2007 – ongoing

Project leader
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Other staff in 2009–10
Sharron Rossow, Chris Crowley and Rodney Stevenson

Objectives
- Determine the seed longevity of several priority weeds found in central and northern Queensland, for which data are currently limited.
- Develop germination and viability testing techniques for the above-mentioned weeds if none is available.
- Disseminate the results and implications of the research through scientific publications, media stories and presentations to relevant stakeholder groups.

Rationale
Currently there are many declared weeds for which we know very little about seed ecology, particularly germination requirements and longevity. Such information is important in control programs as it allows land managers to plan activities based on the length of time that will be required to deplete seed banks in the absence of any replenishment. This project will provide this information priority species in central and northern Queensland.

Methods
We establish a long-term experiment on the grounds of TWRC designed to determine the seed longevity of up to 12 priority weed species. The experiment uses a 2 × 2 × 4 × 12 factorial design, with factor A comprising two soil types (alluvial and clay), factor B two levels of grass cover (nil or full cover), factor C four burial depths (0, 2.5, 10 and 20 cm) and factor D 10 sampling periods (0, 3 and 6 months; 1, 2, 4, 6, 8, 10 and 13 years). Each treatment is replicated four times.

Species buried so far include seven Class 2 or Class 3 declared weeds—mesquite (*Prosopis pallida*), prickly acacia (*Acacia nilotica* ssp. *indica*), chinee apple (*Ziziphus mauritiana*), Captain Cook tree (*Cascabella thevetia*) (both yellow- and peach-flowering types), calotrope (*Calotropis procera*), lantana (*Lantana camara*) (both orange- and pink-flowering types), and parthenium (*Parthenium hysterophorus*)—along with three other species—yellow bells (*Tecoma stans*), neem (*Azadirachta indica*) and leucaena (*Leucaena leucocephala* ssp. *glabrata*).

Progress in 2009–10
Preliminary results suggest that chinee apple and yellow oleander have short-lived seed banks, with no viable seed recorded after 18 months burial. To confirm this finding, we will retrieve seeds of these species again after two years burial (October 2010) and also collect and bury a fresh batch of seeds to expose them to another set of environment conditions.

Mesquite, calotrope, yellow bells and neem have also demonstrated a rapid loss of viable seed from the seed bank following burial (<3% viability after 12 months burial). In contrast, prickly acacia, leucaena, lantana and parthenium are showing a greater level of persistence.

Funding in 2009–10
- Queensland Government
- Land Protection Fund ($58 000)

Collaborators
- Bob J. Mayer, Senior Biometrician (DEEDI, Oonoonba)
- Carole Wright, Biometrician (DEEDI, Oonoonba)

More information
For further information on this research project, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

6. Controlling calotrope (*Calotropis procera*) in northern Australia

Project dates
June 2010 – June 2014

Project leader
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Other staff in 2009–10
Wayne Vogler

Objective
Develop improved control options for calotrope.

Rationale
Several prioritisation processes have listed calotrope (*Calotropis procera*) as an economic and environmental weed in northern Australia's rangelands. Native to tropical Africa and Asia, calotrope has spread into areas of northern Queensland, the Northern Territory and the Kimberley in Western Australia, but this is still only a small portion of its potential range.

A national literature review by Grace (2006) and an MLA-sponsored workshop in 2007 identified distribution and spread, methods of control, biology, grazing effects and monitoring as key research gaps that require investigation to fully understand the invasiveness and potential impacts of calotrope and how best to manage it.

Photo 1. An infestation of calotrope in north Queensland.

This project is part of a larger collaborative MLA-funded project that is aimed at improving our understanding of the distribution and rate of spread, reproductive biology, invasiveness and control of calotrope. Biosecurity Queensland is focussing on improving control options, with the other aspects investigated primarily by Charles Darwin University and NRETAS, Northern Territory.

Methods
Initially, we focus on identifying herbicide products and techniques that can be easily and practically used as part of day-to-day activities to control isolated calotrope plants without the need for excessive equipment. We compare new and unregistered products with currently available options and also research seasonal efficacy.

We explore in detail the efficacy of mechanical control by first quantifying the level of damage required to cause mortality and then comparing the effectiveness of a range of available equipment.

We also establish an adaptive management site in either the Barkly Tablelands or the Gulf Region of Queensland to test cost-effective and best practice control options based on stakeholder feedback and research results.

An advisory committee, initially set up after the 2007 MLA workshop, is re-established to oversee the project and ensure it achieves its objectives. We also hold an initial stakeholder workshop to present the proposed research program and ensure that it is appropriate to answer critical information gaps on calotrope.

Progress in 2009–10
A contract has been signed with MLA to complete the identified research, and negotiations are underway between Biosecurity Queensland, NRETAS and Charles Darwin University to implement third party agreements around specific research to be undertaken by the respective organisations.

We have further held some preliminary meetings with landholders and organisations to identify the highest priority research questions that need to be answered in order to improve management of calotrope.

Funding in 2009–10
- MLA ($200 000)
- Queensland Government

Collaborators
- Charles Darwin University
- NRETAS, Northern Territory
- Barkly Landcare Association

More information
Key publications

Vitelli, J., Madigan, B., Wilkinson, P. and van Haaren, P. 2008. Calotrope (*Calotropis procera*) control. *The Rangeland Journal* 30(3): 339–348.

Grace, B.S. 2006. The biology of Australian weeds 45. *Calotropis procera* (Aiton) W.T. Aiton. *Plant Protection Quarterly* 21(4): 152–160.

For further information on this research project and access to key publications, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

7. Herbicide application research

Project dates

June 2008 – ongoing

Project leader

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Other staff in 2009–10

Dannielle Brazier

Objectives

- Evaluate the effectiveness of chemical control techniques, including basal bark spraying, foliar spraying, cut stump, stem injection and splatter gun spraying, on Captain Cook tree.
- Evaluate the effectiveness of stem injection on prickly acacia, chinee apple and calotrope.
- Evaluate different herbicides using the cut stump technique on chinee apple and using water as the carrier.

Rationale

Captain Cook tree (*Cascabella thevetia*) is a Class 3 weed (a garden escapee) that has established some relatively large infestations in northern Queensland, particularly along riverbanks of the Douglas River and major creeks of the lower and upper Burdekin catchment near Mingela and Ravenswood.

Developing effective control techniques is essential to stopping the continued spread of this weed. Presently, there is no registered chemical available for its control.

There is a need to further explore water based herbicide applications that are suitable for sensitive environments and cheaper than those that use diesel as the carrier. We investigate stem injection and cut stump as possible methods to reduce the amount of chemical required and to eliminate the diesel component for treating large established trees along creek systems.

Methods

Captain Cook tree trials

We conduct four experiments near Mingela to determine which herbicides and rates are most effective in controlling Captain Cook tree using basal bark spraying, foliar spraying, cut stump, stem injection and splatter gun spraying techniques. Experiments for each technique are completely randomised, incorporating three replications. We test the efficacy of herbicides on three size classes (<20, 21–50 and >51 mm basal diameter at 20 cm above ground). Each size class comprises 10 plants that are tagged and painted for future reference and we also record their reproductive status prior to treatment.

Based on results from the screening trials, we undertake further trials to refine rates for the most promising herbicides. These are conducted at the same site and use a similar methodology to the screening trials.

Stem injection and cut stump trials

We conduct stem injection trials on prickly acacia, chinee apple and calotrope using a completely randomised block design. Each treatment is replicated three times and individual plots comprise 20 plants. We apply 1 mL of herbicide mix from a Phillips tree injector gun into incisions with centres 7 cm apart. Incisions are cut with a tommyhawk axe at an angle of approximately 10 degrees to the stem at a height that is comfortable to the applicator. We also record the number and height of incisions for each plant. Herbicides used for this trial are either registered for stem injection for other species or their active ingredients have been found effective in controlling these weeds when using other application methods.

For the cut stump trials on chinee apple, we compare water-based herbicide applications with traditional diesel-based options. The methodology used is similar to the stem injection trials, except that we cut plants down using a chainsaw and then apply herbicides via a Phillips tree injector gun.

Based on results from the screening trials, we undertake further trials to refine rates for the most promising herbicides. These are conducted at the same site and use a similar methodology to the screening trials.

Photo 1. Effect of herbicide application by stem injection on a prickly acacia plant. (a) a healthy prickly acacia plant; (b) Project leader John McKenzie conducting stem injection treatment and (c) mortality of the same plant following treatment.

Progress in 2009–10

Captain Cook tree trials

Following earlier screening trials (reported in *Technical highlights 2008-09*), rate screening trials for basal bark spraying, foliar spraying and cut stump treatment as well as an initial screening trial for splatter gun spraying have been established. Herbicides and rates used are summarised in Table 1.

Efficacy of various herbicides applied as a stem injection treatment in an initial rate screening trial is summarised in Table 2. An additional stem injection rate screening trial has also been established to assess seasonal efficacy of herbicides (Table 1).

Stem injection and cut stump trials

Calotrope

A stem injection screening trial has been conducted south of Greenvale on a tributary of the Clarke River. Based on the results, we have now initiated a rate screening trial near Georgetown (along the Gilbert River). Herbicides, rates used and their efficacy in the initial screening trial are summarised in Table 3.

Prickly acacia

A stem injection screening trial was established on mature prickly acacia trees on a property near Stamford. A number of herbicides are showing very good efficacy on prickly acacia using the stem injection application technique (Photo 1).

Based on the results, we have now initiated a rate screening trial, also at Stamford. The methodology used was similar to the screening trial, except that we increased the distance between incision centres depending on chemical, plant size and label recommendations for other species. The amount of herbicide applied also depended on plant size but was either 1 mL or 2 mL per cut. For this trial, we did not apply a wetting agent with the herbicide. Herbicides, rates used and their efficacy in the initial screening trial are summarised in Table 4.

Chinee apple

Screening trials for the stem injection and cut stump applications on chinee apple are underway. Herbicides, rates used and their efficacy 18 months after treatment in the cut stump trial are summarised in Table 5.

Funding in 2009–10

Queensland Government

More information

For further information on this research project, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

Table 1. Treatments, active ingredients and rates used in Captain Cook tree rate screening trials at Mingela. (Stem injection treatments refer to the second rate screening trial. Splatter gun treatments refer to the initial screening trial. * = double application height (1 m above ground); D = diesel; Ww = water + wetter.)

Treatment	Active ingredient	Rate and carrier
Basal bark	fluroxypyr (333 g L^{-1})	1:112D
Basal bark*	fluroxypyr (333 g L^{-1})	1:112D
Basal bark	control	1D
Basal bark*	control	1D
Cut stump	fluroxypyr (333 g L^{-1})	1:112Ww
Cut stump	fluroxypyr (333 g L^{-1})	1:55Ww
Cut stump	fluroxypyr (333 g L^{-1})	1:55D
Cut stump	control	D
Cut stump	control	Ww
Foliar	fluroxypyr (333 g L^{-1})	1:334Ww
Foliar	fluroxypyr (333 g L^{-1})	1:167Ww
Foliar	aminopyralid (10 g L^{-1}) + fluroxypyr (140 g L^{-1})	1:140Ww
Foliar	triclopyr (300 g L^{-1}) + picloram (100 g L^{-1}) + aminopyralid (8 g L^{-1})	1:300Ww
Foliar	control	Ww
Stem injection	glyphosate (360 g L^{-1})	1:0w
Stem injection	glyphosate (360 g L^{-1})	1:0
Stem injection	triclopyr (200 g L^{-1}) + picloram (100 g L^{-1})	1:4Ww
Stem injection	triclopyr (200 g L^{-1}) + picloram (100 g L^{-1})	1:4W
Stem injection	control	Ww
Stem injection	control	W
Splatter gun	fluroxypyr (333 g L^{-1})	1:9Ww
Splatter gun	aminopyralid (10 g L^{-1}) + fluroxypyr (140 g L^{-1})	1:3Ww
Splatter gun	glyphosate (360 g L^{-1})	1:9Ww
Splatter gun	control	Ww

Table 2. Mortality of Captain Cook tree following stem injection treatment in the first rate screening trial. (Mortality values followed by the same superscript letter are not significantly different, p <0.05. Carrier for all treatments and control was water + wetter.)

Active ingredient	Rate	Mortality (%)
glyphosate (360 g L^{-1})	1:13	7^{d}
glyphosate (360 g L^{-1})	1:9	28^{c}
imazapyr (150 g L^{-1}) + glyphosate (150 g L^{-1})	1:5	87^{a}
imazapyr (150 g L^{-1}) + glyphosate (150 g L^{-1})	1:3	87^{a}
glyphosate (360 g L^{-1})	1:2	70^{ab}
glyphosate (360 g L^{-1})	1:3	53^{b}
control		0^{d}

Table 3. Active ingredients and rates used for calotrope stem injection trials and mortality achieved during initial screening. (Mortality values followed by the same superscript letter are not significantly different, p <0.05. Carrier for all treatments and control was water + wetter.)

Trial	Active ingredient	Rate	Mortality (%)
Screening	triclopyr (200 g L^{-1}) + picloram (100 g L^{-1})	1:3	87^{ab}
Screening	triclopyr (200 g L^{-1}) + picloram (100 g L^{-1})	1:7	57^{cd}
Screening	glyphosate (360 g L^{-1})	1:0	77^{abc}
Screening	glyphosate (360 g L^{-1})	1:1	50^{cd}
Screening	metsulfuron methyl (600 g kg^{-1})	1g $1L^{-1}$	10^{ef}
Screening	metsulfuron methyl (600 g kg^{-1})	1g $2L^{-1}$	3^{f}
Screening	control		7^{ef}
Screening	imazapyr (150 g L^{-1}) + glyphosate (150 g L^{-1})	1:3	77^{abc}
Screening	imazapyr (150 g L^{-1}) + glyphosate (150 g L^{-1})	1:8	97^{a}
Screening	control		0^{f}
Screening	2,4-D (625 g L^{-1})	1:5	60^{bcd}
Screening	2,4-D (625 g L^{-1})	1:1	33^{de}
Rate screening	triclopyr (200 g L^{-1}) + picloram (100 g L^{-1})	1:4	
Rate screening	2,4-D (300 g L^{-1}) + picloram (75 g L^{-1})	1:3	
Rate screening	2,4-D (625 g L^{-1})	1:7	
Rate screening	glyphosate (360 g L^{-1})	1:0	
Rate screening	glyphosate (360 g L^{-1})	1:1	
Rate screening	imazapyr (150 g L^{-1}) + glyphosate (150 g L^{-1})	1:4	
Rate screening	control		

Table 4. Active ingredients and rates used for prickly acacia stem injection trials and mortality achieved during initial screening. (Mortality values followed by the same superscript letter are not significantly different, p <0.05. Ww = water + wetter; W = water.)

Trial	Active ingredient	Rate and carrier	Mortality (%)
Screening	triclopyr (200 g L^{-1}) + picloram (100 g L^{-1})	1:2.3Ww	100^{a}
Screening	2,4-D (300 g L^{-1}) + picloram (75 g L^{-1})	1:1.5Ww	97^{ab}
Screening	fluroxypyr (333 g L^{-1})	1:2Ww	76^{b}
Screening	aminopyralid (10 g L^{-1}) + fluroxypyr (140 g L^{-1})	1:1Ww	83^{ab}
Screening	2,4-D (625 g L^{-1})	1:4Ww	0^{d}
Screening	imazapyr (150 g L^{-1}) + glyphosate (150 g L^{-1})	1:4Ww	5^{d}
Screening	glyphosate (360 g L^{-1})	1:11Ww	8^{d}
Screening	glyphosate (360 g L^{-1})	1:2Ww	30^{c}
Screening	hexazinone (250 g L^{-1})	1:2Ww	3^{d}
Screening	control	Ww	7^{d}
Rate screening	triclopyr (200 g L^{-1}) + picloram (100 g L^{-1})	1:4W	
Rate screening	2,4-D (300 g L^{-1}) + picloram (75 g L^{-1})	1:1.5W	
Rate screening	glyphosate (360 g L^{-1})	1:0.5W	
Rate screening	control	W	

Table 5. Treatments, active ingredients and rates used in chinee apple screening trials. (Mortality and regrowth values followed by the same superscript letter are not significantly different, p <0.05. MAT = months after treatment; D = diesel; Ww = water + wetter.)

Treatment	Active ingredient	Rate and carrier	Regrowth (% change in height) 6 MAT	Mortality (%) 18 MAT
Cut stump	triclopyr (200 g L^{-1}) + picloram (100 g L^{-1})	1:4Ww	1^{a}	45^{b}
Cut stump	triclopyr (300 g L^{-1}) + picloram (100 g L^{-1}) + aminopyralid (8 g L^{-1})	1:4Ww	0^{a}	73^{a}
Cut stump	fluroxypyr (200 g L^{-1})	1:5Ww	1^{a}	37^{bc}
Cut stump	aminopyralid (10 g L^{-1}) fluroxypyr (140 g L^{-1})	1:5Ww	3^{a}	22^{cd}
Cut stump	metsulfuron methyl (600 g kg^{-1})	1g $1L^{-1}$Ww	75^{e}	0^{e}
Cut stump	imazapyr (150 g L^{-1}) + glyphosate (150 g L^{-1})	1:8Ww	16^{bc}	7^{de}
Cut stump	glyphosate (360 g L^{-1})	1:2Ww	86^{e}	0^{e}
Cut stump	glyphosate (360 g L^{-1})	1:2Ww	52^{d}	0^{e}
Cut stump	2,4-D (625 g L^{-1})	1:4Ww	10^{abc}	5^{de}
Cut stump	triclopyr (240 g L^{-1}) + picloram (120 g L^{-1})	1:6D	4^{a}	22^{cd}
Cut stump	picloram (43 g kg^{-1})	1:0	16^{c}	18^{cde}
Cut stump	control	Ww	100^{f}	0^{e}
Stem injection	triclopyr (200 g L^{-1}) + picloram (100 g L^{-1})	1:4Ww		
Stem injection	2,4-D (300 g L^{-1})+ picloram (75 g L^{-1})	1:1.5Ww		
Stem injection	2,4-D (625 g L^{-1})	1:6Ww		
Stem injection	imazapyr (150 g L^{-1}) + glyphosate (150 g L^{-1})	1:4Ww		
Stem injection	glyphosate (360 g L^{-1})	1:2Ww		
Stem injection	hexazinone (250 g L^{-1})	1:2Ww		
Stem injection	control	Ww		

8. Florestina (*Florestina tripteris*) herbicide trial

Project dates

March 2007 – December 2009 (completed)

Project leader

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Other staff in 2009–10

Dannielle Brazier, Shane Campbell and Joe Vitelli

Objectives

- Complete a broad chemical screening trial to identify potential herbicides for control of florestina.
- Establish rate response trials using the herbicides from the screening trial that provided high mortality and some residual control of seedling regrowth.
- Establish a demonstration site incorporating the herbicides and rates that provide highest mortality and residual control while having limited effect on the pasture species present.
- Seek registration of the most effective herbicides through APVMA to aid in the management of florestina.

Rationale

Florestina (*Florestina tripteris*), like parthenium, was accidently introduced into Australia in contaminated pasture grass seed in the 1960s. Infestations are found in the Tambo area in central western Queensland and at Barcaldine. Florestina can start flowering relatively quickly after rain, allowing it to survive in environments with limited and variable rainfall and in disturbed areas (e.g. road verges, fence lines or well-utilised pastures). A cost-effective herbicide would be of great value in the management of florestina.

Methods

Chemical screening trial

To determine the efficacy and the residual effects of a range of herbicides, we undertake a randomised complete block experiment with each treatment replicated four times. The field site is located on a property 30 km south-east of Barcaldine. We count both adult and seedling (non-flowering) florestina plants present in plots (4 m^2) before herbicide application. We then apply chemical mixes using an Ag-Murf® pressurised applicator at a volume of 1500 L ha^{-1}. Post-treatment measurements of plant mortality and seedling regrowth are also undertaken.

Rate response trials

Rate response trials are conducted at the same site and use a similar design and methodology to the screening trial. Herbicides in the first rate response trial are chosen based on their effectiveness in the screening trial. Picloram and 2,4-D are also trialled individually to give a better understanding of the effect of each active ingredient on florestina.

Treatments used in the second rate response trial are based on the chemicals giving the greatest residual effect in the previous trials. Each treatment is applied using a four-wheel motorbike with a rear-mounted boom for a distance of 50 m at a spray volume of 67 L ha^{-1} and is replicated four times. Assessments are made within each treatment in two 4 m^2 plots, using the same rationale as in the previous trials.

Progress in 2009–10

For findings from the screening and rate response trials see *Technical highlights 2008–09*. A minor use permit (PER11920) has now been obtained from APVMA. This allows for the use of registered products containing 600 g L^{-1} metsulfuron methyl, 500 g L^{-1} 2,4-D amine and 300 g L^{-1} 2,4-D/75 g L^{-1} picloram as the active ingredient as a spot spray or boom spray application. The permit is valid until 31 March 2015.

A final report outlining the results from all trials has been completed and submitted to Desert Channels Queensland, who provided the initial funding to undertake this work.

Funding in 2009–10

Queensland Government

Collaborators

Desert Channels Queensland

More information

For further information on this research project, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

9. Biological control of bellyache bush (*Jatropha gossypiifolia*)

Project dates

July 2007 – June 2011

Project leader

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Other staff in 2009–10

Bill Palmer, Di Taylor and Matthew Shortus

Objectives

- Identify suitable biological control agents for host-specificity testing through review of earlier survey work and exploration (in collaboration with CSIRO).
- Import potential biological control agents, conduct host-specificity tests and seek approval of host-specific agents for field release.
- Conduct pathogenicity and host range testing of the Jatropha rust fungus (*Phakopsora jatrophicola*) as a potential biocontrol agent for bellyache bush.

Rationale

Bellyache bush (*Jatropha gossypiifolia*) is a serious and expanding weed of northern Queensland. It invades rangeland, particularly in riparian zones, and forms dense thickets that reduce productivity and biodiversity. All parts of the plant, especially the seeds, are toxic to grazing animals. Bellyache bush is a declared target for biological control and an effective biocontrol agent is needed to halt the spread of bellyache bush and reduce its impact. The only biological control agent released to date, the bellyache bush jewel bug (*Agonosoma trilineatum*), is not known to be established in the field. Hence, the bellyache bush biological control program was recommenced in 2007 to further screen potential agents identified during earlier surveys in Central America and to conduct additional surveys in South America.

Methods

Native range surveys

CSIRO Entomology staff based at the Mexican Field Station conduct surveys to catalogue insects associated with bellyache bush in North America (Mexico), Central America (Nicaragua, Costa Rica, Honduras and Guatemala), South America (Colombia, Venezuela, Ecuador, Brazil, Argentina, Paraguay and Bolivia) and the Caribbean (Puerto Rico, St Kitts and Dominica).

Surveys for potential biological control agents in Cuba are conducted by Stefan Neser of ARC-PPRI, South Africa.

CABI in Mexico, in collaboration with staff from the CSIRO Mexican Field Station, conducts surveys for the presence of spores of the Jatropha rust fungus (*Phakopsora jatrophicola*) on bellyache bush and other potential alternate hosts (e.g. *Jatropha curcas*) in Mexico and Venezuela.

Host-specificity tests

CABI Europe–UK exports freshly collected spore material of *P. jatrophicola* to facilities in the UK—teliospore material is used for subsequent germination and inoculation experiments to attempt to elucidate the rust life cycle. Staff from the CSIRO Mexican Field Station and, if possible, CABI Europe–UK through other collaborative links, collect additional strains of *P. jatrophicola* ex *J. gossypiifolia* from different geographic regions and send them to facilities in the UK. A comparative assessment of infectivity and virulence of the different rust strains towards *J. curcas* and *J. gossypiifolia* is made through inoculation of one selected variety of *J. gossypiifolia* and *J. curcas* with urediniospores following established inoculation protocols. A rust strain both virulent and highly specific to *J. gossypiifolia* is then prioritised and CABI Europe–UK conducts a full host-specificity test for this strain against 34 plant species identified in the test plant list.

Ecological studies

An ecophysiological study examines differences in the rates of photosynthesis, stomatal conductance, respiration and transpiration between three morphologically distinct bellyache bush populations (Queensland bronze, Queensland purple and Queensland green) in relation to leaf age, leaf colour and water stress, using a LI-COR LI-6400 portable photosynthesis system in the glasshouse.

A PhD research project in collaboration with QUT evaluates the differences in genotypic and phenotypic characteristics (seed germination, seedling growth rates, time to reproduction, rate of flower to fruit conversion, reproductive output, and cross- and self-pollination) of different bellyache bush populations (Queensland bronze, Queensland green, Western Australian green, Katherine green and Darwin purple) in Australia. The cross-pollination studies will estimate the heritability of traits of various bellyache bush varieties.

Progress in 2009–10

Native range surveys

In 2009–10 various sites in Mexico and north-western Argentina were surveyed. On the basis of field surveys so far, it is speculated that the native range of *J. gossypiifolia* comprises the countries surrounding the Caribbean Sea, including Mexico, Central America, the northern coast of South America and the Caribbean Islands. Hence, future survey efforts should focus on areas in Central America and the Caribbean Islands, in particular Cuba.

Obtaining permission to collect in, and export potential biological control agents from Cuba has proved to be a very difficult and uncertain process. A visit to Cuba by Stefan Neser (ARC-PPRI, South Africa) is planned for September–October, 2010.

Based on previous survey efforts, two species of tip borers (*Pityophthorus* sp. and *Ormiscus/Eusphyrus* sp.), a seed feeder (*Pachycoris* prob. *fabricii*), an unidentified stem borer (Cerambicidae), and a leaf- and shoot tip–mining larva (*Euxestha abdominalis/E.* aff. *panamena*) have been prioritised for detailed studies.

Various strains of the Jatropha rust *P.jatrophicola* were collected from various regions in Brazil, Mexico, Trinidad and Nicaragua and exported to CABI Europe–UK for host-specificity tests.

Host-specificity tests

On the basis of preliminary host-specificity tests, CABI Europe–UK initiated further screening of additional strains of *P. jatrophicola* from other countries during 2008–09 to identify a strain which was both virulent and highly specific to *J. gossypiifolia* for comprehensive host range studies.

The evaluated rust strains from Brazil, Trinidad and the Mexican Pacific region were able to infect *J. curcas*, causing variable degrees of leaf necrosis and limited sporulation on inoculated leaves (Figure 1). However, as shown during the assessment of the Mexican strain ex El Zapote, Veracruz (W2028), *J. curcas* cannot be regarded as a fully susceptible host of either of the evaluated rust strains (restricted number and size of uredinia; limited sporulation). Furthermore, none of these additional strains proved to be infective and highly host-specific to *J. gossypiifolia*. Based on the extent of leaf necrosis and sporulation recorded on *J. curcas* during greenhouse inoculations, the *P. jatrophicola* strains from Brazil and Trinidad could be considered less virulent compared to the previously assessed rust strain W2028 ex El Zapote, Mexico, while the rust strain from the Mexican Pacific region appears to be more virulent. Dose response experiments using lower urediniospore concentrations for inoculation could be considered for the Brazilian and the Trinidadian rust strain, respectively, in order to establish a more realistic picture of anticipated infection levels of *J. curcas* under field conditions.

Two strains of *P. jatrophicola* collected from *J. gossypiifolia* in Nicaragua failed to establish on the Australian varieties Queensland purple, Kununurra green and Katherine green. Microscopic studies showed evidence of immature uredinia and plant defence reactions on inoculated *J. gossypiifolia* plants, indicating incompatibility interactions between the specific plant biotype and the rust pathotype. It is possible that the Nicaraguan strains of *P. jatrophicola* will equally fail to infect and sporulate on *J. curcas*. Therefore it could be important to establish the susceptibility of all Australian biotypes of *J. gossypiifolia* to these rust strains.

All attempts to rear and test the specificity of the stem-boring weevil *Cylindrocopturus imbricatus* in Australia failed, as adults did not copulate or lay eggs; the reasons for this have not been determined. A colony of *C. imbricatus* was established at the CSIRO Mexican Field Station. Because of the variable results with rearing this species, host-specificity testing based on larval development did not proceed. During field surveys in Mexico *C. imbricatus* emerged from *Xanthium strumarium* (Asteraceae), poss. *Simsia* sp. (Asteraceae) and *J. curcas* (Euphorbiaceae), proving that these species are hosts of *C. imbricatus*. This weevil is clearly not adequately specific to be useful as a biological control agent. In fact, it appears that *J. gossypiifolia* is a poor host of this insect, which would explain the variable results in the trials on rearing methodology.

Ecological studies

The ecophysiological study has been completed and is currently written up for publication. Differences in the rates of photosynthesis, transpiration, respiration and stomatal conductance in response to water stress between the three biotypes were not significant. Photosynthesis was consistently highest for the high water

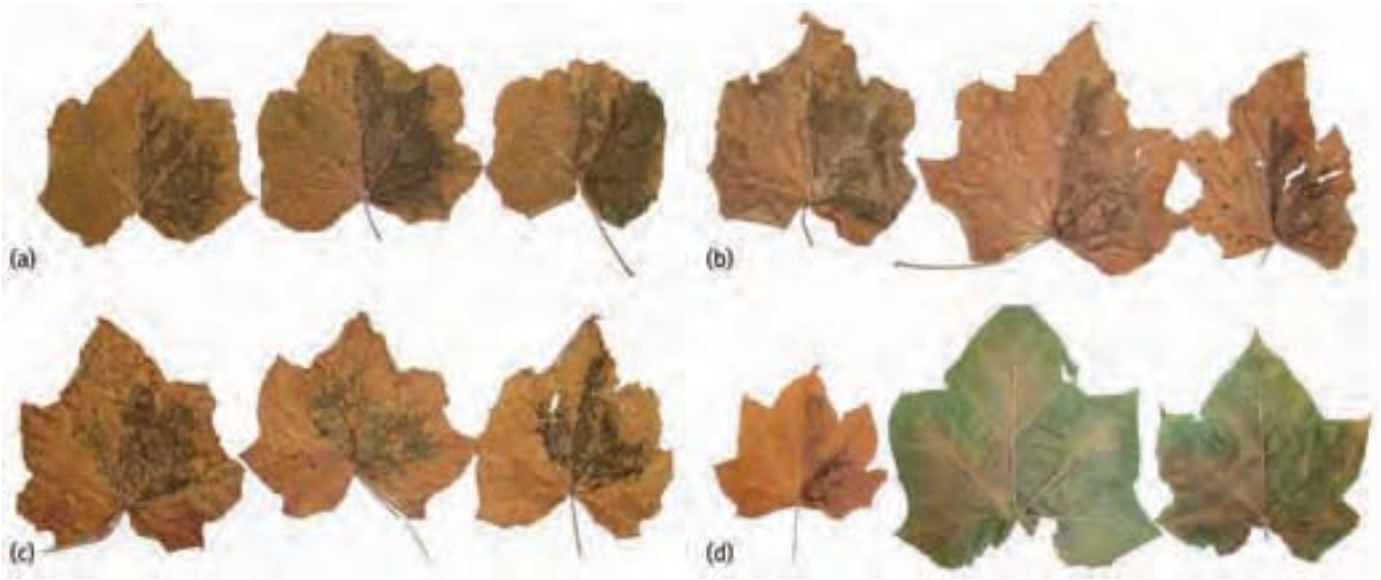

Photo 1. Extent of necrosis caused by different *P. jatrophicola* strains—a) Strain W2028 ex El Zapote, Mexico; b) Strain W2489 ex Brazil; c) Strain W2523 ex Mexico, Pacific coast and d) Strain W2512 ex Trinidad—on *J. curcas* leaves of different ages. View of upper leaf surfaces of mature, fully expanded and apical leaves is shown from left to right. (Photos courtesy of Marion Seier, CABI Europe–UK.)

treatment and lowest for the drought treatment and varied depending on the season in which measurements were made. Water use efficiency decreased linearly with leaf age for all biotypes.

A trial examining the mating compatibility (cross-pollination) of the bellyache bush biotypes and the resulting progeny is ongoing. Preliminary results suggest that the various biotypes are capable of cross-pollinating, but the viability of seeds from such crosses is yet to be examined.

Ms Judith Raue (QUT) commenced her PhD on the phenotypic and genotypic variability of bellyache bush populations in Australia. Seeds of various bellyache bush biotypes in Queensland have been collected and attempts are underway to germinate them in temperature controlled cabinets at QUT.

Funding in 2009–10

- Land Protection Fund ($42 000)
- Queensland Government (Blueprint for the Bush)

Collaborators

- Tim Heard (CSIRO Entomology, Brisbane)
- Stefan Neser (ARC-PPRI, South Africa)
- Judith Raue (Institute for Sustainable Resources, QUT)
- Tanya Scharaschkin (Faculty of Science and Technology, QUT)
- Ricardo Segura (CSIRO Entomology, Mexican Field Station)
- Marion Seier (CABI Europe–UK, United Kingdom)

More information

Key publications

Heard, T.A., Chan, R.R., Senaratne, K.A.D.W., Palmer, W.A., Lockett, C.J. and Lukitsch, B. 2009. *Agonosoma trilineatum* (Heteroptera: Scutelleridae) a biological control agent of the weed bellyache bush, *Jatropha gossypiifolia* (Euphorbiaceae). *Biological Control* 48(2): 196–203.

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For further information on this research project and access to key publications, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

10. Biological control of parthenium (*Parthenium hysterophorus*)

Project dates

May 2007 – May 2015

Project leader

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Other staff in 2009–10

Mariano Treviño, Catherine Lockett, Wilmot Senaratne and Asad Shabbir (UQ PhD student)

Objectives

- Monitor the field persistence and abundance of parthenium biological control agents.
- Identify climatically suitable areas for the biological control agents using CLIMEX models and introduce the agents in suitable areas where they do not occur currently.
- Evaluate the role of beneficial competitive plants to enhance the effectiveness of weed biological control agents.

Rationale

Parthenium (*Parthenium hysterophorus*) is a Weed of National Significance (WONS) and a Class 2 declared weed in Queensland. Biological control is one of the most effective and economically viable management options. Among the various biological control agents introduced against parthenium in Queensland, the summer rust (*Puccinia xanthii* var. *parthenii-hysterophorae*, previously reported as *P. melampodii*) is an agent suited to areas with hot and dry weather conditions. It was introduced from Mexico in 1999 and released at more than 50 infested sites in Queensland. The clear-wing moth (*Carmenta ithacae*), also native to Mexico, was released from 1998 to 2002. The stem-galling weevil (*Conotrachelus albocinereus*) from Argentina was released in Queensland from 1995 to 2000. Although all three agents have established in the field, their incidence and abundance in parthenium infestations in central and north Queensland is not fully known.

Success or failure of weed biological control agents is often determined by climatic factors. CLIMEX models have been used widely to identify climatically suitable areas for biological control agent releases. So far, no such information is available for parthenium biological control agents in Australia.

The role of competition from beneficial plants in managing parthenium weed is widely known. So far, however, no information is available on the potential role of various native and introduced pasture plants in enhancing the effectiveness of parthenium biological control agents in Australia. Identification of beneficial plants exhibiting high competitive indices would help to manage parthenium more effectively.

Methods

Biological control agent monitoring

Parthenium sites in central and north Queensland are monitored at the end of the parthenium growing season. At each site, we record the incidence and abundance of various biological control agents—the summer rust (*P. xanthii* var. *parthenii-hysterophorae*), the clear-wing moth (*C. ithacae*) and the stem-galling weevil (*C. albocinereus*)—along with information on other established biological control agents and the abundance of parthenium.

CLIMEX modelling

We build a CLIMEX model to predict climatically suitable areas for the clear-wing moth in Australia. First, the climate profile of the moth is determined by recursively testing various sets of parameter values until the model's distribution matches the moth's recorded native range distribution on parthenium in Mexico. The estimated parameters are then used to predict its potential distribution in Australia.

Beneficial plant competition and biological control

We conduct an experiment with 200 potted plants to quantify the effect of two competitive pasture species—bull Mitchell grass (*Astrebla squarrosa*) and butterfly pea (*Clitoria ternatea*)—at five combinations of low (4:0, 3:1, 2:2, 1:3, 0:4) and high (6:0, 4:2, 3:3, 4:2, 0:6) density, with and without the biological control agent *Epiblema strenuana* in two adjacent insect-proof shadehouses. *E. strenuana* galls on parthenium weed plants are collected from central Queensland and brought to AFRS. We then cover galls with moistened paper towels and put them in insect cages placed in a glasshouse. Emerging adult moths are released (one adult moth per plant) onto the plants in one of the insect-proof shadehouses (with biological control) at eight weeks after initiation of the trial. Plants in the second insect-proof shadehouse (no biological control) are kept free of any biological control agents. We then monitor populations of *E. strenuana* and damage levels (e.g. number of galls per plant) at monthly intervals. Simultaneously, we monitor the shadehouse with no biological control to check that the plants are free of any agents. After four months, we harvest all plants and record various plant parameters (e.g. height, above-ground biomass, no. of branches, number of flowers and seed fill). We calculate competitive indices for both competitive plant species with and without the biological control agent.

Progress in 2009–10

In central Queensland, we surveyed seven parthenium sites in March 2010 and 17 sites in April 2010. Surveys at three sites in north Queensland were conducted in May 2010.

*Parthenium summer rust (*Puccinia xanthii *var.* parthenii-hysterophorae*)*

Presence of the summer rust was evident at all three sites in north Queensland (Cardigan Station, Felspar and Plain Creek), but the proportion of plants with summer rust infection varied widely between the sites (Figure 1). Overall, the proportion of leaves with summer rust infection remained low (Figure 1). In central Queensland, the rust

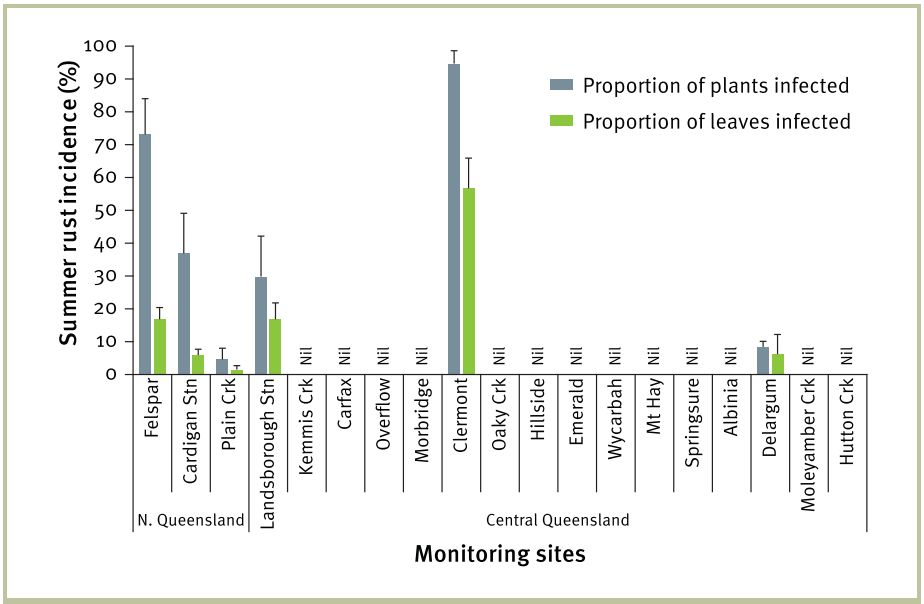

Figure 1. Incidence of *P. xanthii* var. *parthenii-hysterophorae* in Queensland. (Vertical bars indicate the SE of the means.)

was present at only three out of 16 sites (<20%). Rust incidence remained very low except at Clermont, where 95% of plants showed summer rust infection in 57% of leaves (Figure 1).

*Parthenium clear-wing moth (*Carmenta ithacae*)*

We have previously confirmed field establishment of the clear-wing moth at five (Wycarbah, Mt Hay, Long Island, Overflow and Carfax) of the 13 release sites and two non-release sites nearby (Gracemere, 20 km from Long Island and North Wycarbah, 5 km from Wycarbah), all in central Queensland. However, in 2010, the clear-wing moth was recovered from only one of these sites (Carfax).

The CLIMEX model developed for the potential geographic range of the clear-wing moth in Australia is currently extrapolated to other countries to determine whether parthenium-infested areas in Africa and South Asia are climatically suitable for this biological control agent.

*Parthenium stem-galling weevil (*Conotrachelus albocinereus*)*

In central Queensland, the stem-galling weevil has been recovered from only one (Moleyamber Creek) of the 17 sites surveyed. *C. albocinereus* incidence at this site remained low (20%), with an average of one larva per infested plant. Limited establishment of this agent could be due to the dominance of the stem-galling moth (*E. strenuana*) in all parthenium-infested areas. Both the stem-galling moth and the stem-galling weevil share a similar feeding niche.

Other agents

In February 2010, we accompanied researchers Dr Andrew McConnachie and Lorraine Strathie from ARC-PPRI to field sites in central Queensland to collect parthenium biological control agents. Two agents, the seed-feeding weevil (*Smicronyx lutulentus*) (Photo 1) and the stem-galling moth (*E. strenuana*) were collected and exported to South Africa for further host-specificity tests. If found host-specific, these two agents will be released in South Africa and Ethiopia.

The incidence and abundance of other biological control agents (e.g. *E. strenuana*, *Zygogramma bicolorata* and *Listronotus setosipennis*) remained low in 2010 compared to previous years. However, an outbreak of *S. lutulentus* was observed in the Rockhampton region in February 2010.

Beneficial plant competition and biological control

The experiment was initiated in September 2009 and completed in January 2010. Preliminary results suggest that *E. strenuana* enhanced the competitive index values of the native bull Mitchell grass and the introduced butterfly pea legume by a factor of +0.1 and +0.2 respectively. Data analyses for the combined effects of the biological control agent and competitive plants on other growth and reproductive attributes of parthenium weed are in progress.

Funding in 2009–10

Queensland Government

Photo 1. Adult *S. lutulentus* weevil.

Collaborators

Prof Steve Adkins (School of Land, Crop and Food Sciences, UQ)

More information

Key publications

Dhileepan, K. and Strathie, L. 2009. *Parthenium hysterophorus* L. (Asteraceae). In: *Biological control of tropical weeds using arthropods*. R. Muniappan, G.V.P. Reddy and A. Raman, eds. Cambridge University Press, Cambridge. pp. 272–316.

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For further information on this research project and access to key publications, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

11. Biological control of prickly acacia (*Acacia nilotica* ssp. *indica*)

Project dates

January 2007 – December 2012

Project leader

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Other staff in 2009–10

A. Balu, M. Senthilkumar, S. Murugesan and P. Senthilkumar (Institute of Forest Genetics and Tree Breeding);
Syed Irfan Ahmed, K. K. Srivastava, Sangeetha Singh, Naveen Sharma, Mahadeo Gorain and Anamika Sharma (Arid Forest Research Institute)

Objectives

- Survey and catalogue insects and pathogens associated with prickly acacia in India.
- Assess the host range of insects and pathogens based on host plant use in the field.
- Confirm primary host status of prickly acacia for agents identified through preliminary host range testing.
- Quantify the impact of native insect herbivores on the survival and growth of prickly acacia seedlings.
- Prioritise potential biocontrol agents on the basis of likely impacts on the weed.
- Seek and obtain approval from the National Biodiversity Authority of India to export prioritised agents to Australia for further host-specificity tests.

Rationale

Prickly acacia (*Acacia nilotica* ssp. *indica*) is a WONS and a Class 2 declared weed in Queensland. The plant is widespread throughout the grazing areas of western Queensland, where it costs primary producers $9 million per year by decreasing pasture production and hindering the mustering of livestock. Biological control research has been in progress since the 1980s, but with limited success to date. Improved climatic modelling and genetic studies have suggested that the search for biological control agents should be concentrated in India, the native range source of the prickly acacia populations in Australia. The occurrence of several native *A. nilotica* subspecies, along with other native and non-native *Acacia* species (including species native to Australia), highlights the advantage of conducting surveys in India where the field host-specificity of potential agents could be determined.

Methods

Our collaborators in India—the Arid Forest Research Institute and the Institute of Forest Genetics and Tree Breeding—conduct surveys in natural groves and plantations in Rajasthan, Gujarat, Tamil Nadu and Karnataka states at regular intervals (four to six times a year, covering all seasons) to catalogue insect herbivores and plant pathogens associated with various subspecies of *A. nilotica* in India.

In Tamil Nadu, the survey includes the two subspecies *indica* and *tomentosa*. In Karnataka, the survey includes the two subspecies *indica* and *cupressiformis*. Survey sites are predominantly forestry plantations in tank beds and isolated plants on the roadside or on bunds of agricultural lands. In Gujarat and Rajasthan, the survey also includes two subspecies each—*indica* and *hemispherica* in Gujarat and *indica* and *cupressiformis* in Rajasthan. Survey sites include both natural groves and forestry plantations. In all surveyed states, predetermined sites are sampled at quarterly intervals and surveys cover a range of age groups from seedlings to mature trees. In addition, other adjacent *Acacia* species are also sampled to monitor the field host-specificity of recorded insects and plant pathogens.

The impact of native insect herbivores on seedling survival and growth under field conditions is evaluated in exclusion trials conducted over two years at four sites each in Rajasthan (Hanumangarh, Desuri, Bharatpur and Jodhpur) and Gujarat (Gandhinagar, Nadyad, Junagarh and Bhuj), and two sites in Tamil Nadu (Coimbatore and Thoppur) (Photo 1). At each site, staff are maintaining potted *A. nilotica* seedlings, with half of the seedlings protected from insect herbivores (by spraying insecticides at fortnightly intervals) and the remaining half exposed to insect herbivores (by spraying with water). We sample the potted plants at quarterly intervals and record the incidence and abundance of various insects, along with details on several plant parameters (e.g.

Photo 1. Dr K. Dhileepan inspects exclusion trial at Coimbatore, Tamil Nadu, India.

Photo 2. Dr K. Dhileepan discussing no-choice host-specificity testing for the babul scale (*Anomalococcus indicus*) with scientists at the Institute of Forest Genetics and Tree Breeding, Coimbatore, Tamil Nadu, India.

Figure 1. Survey sites in Tamil Nadu and Karnataka, India.

defoliation levels, plant height, number of leaves, number of branches, basal stem diameter, above-ground and below-ground biomass, etc.). This information is used for prioritising agents for more detailed studies, including host-specificity tests.

Specialist insect herbivores and plant pathogens exhibiting host-specificity in field surveys are tested in no-choice and choice trials in the glasshouse and field cages to confirm host-specificity (Photo 2).

Progress in 2009–10

Native range surveys

In all surveyed states (Tamil Nadu, Karnataka, Rajasthan and Gujarat), *A. nilotica* ssp. *indica* was the most prevalent and widespread subspecies. In Tamil Nadu, ssp. *tomentosa* occurred with ssp. *indica* at some survey sites. In Karnataka, ssp. *cupressiformis* co-occurred with ssp. *indica* at Chamrajnagar district bordering Tamil Nadu. In Gujarat, ssp. *hemispherica* was prevalent in protected nature reserves and national parks (e.g. Gir Forest) and along the southern coast. In Rajasthan, ssp. *cupressiformis* was widespread and co-occurred with ssp. *indica* throughout the state.

In southern India, surveys were conducted at 70 sites in Tamil Nadu and eight sites in Karnataka (Figure 1). In north-western India, surveys were conducted at 22 sites in Rajasthan and 48 sites in Gujarat (Figure 2). So far, we have recorded 48 species of insects and 14 diseases on prickly acacia in Tamil Nadu and Karnataka. In Rajasthan and Gujarat, we have recorded 14 insect species and 11 diseases.

Most of the insect species and plant pathogens recorded are known to have wide host ranges. However, the prickly acacia galling rust (*Ravenelia acacia-arabicae*, previously reported as *R. evansii*), which infected leaves and induced galls on the rachises and green pods, was observed in the field in Tamil Nadu only on A. *nilotica* ssp. *indica* and not on other subspecies of *A. nilotica* or other co-occurring *Acacia* species. A new rust infecting prickly acacia leaves (Photo 3) was also recorded in Gujarat in January 2010. According to Dr Roger

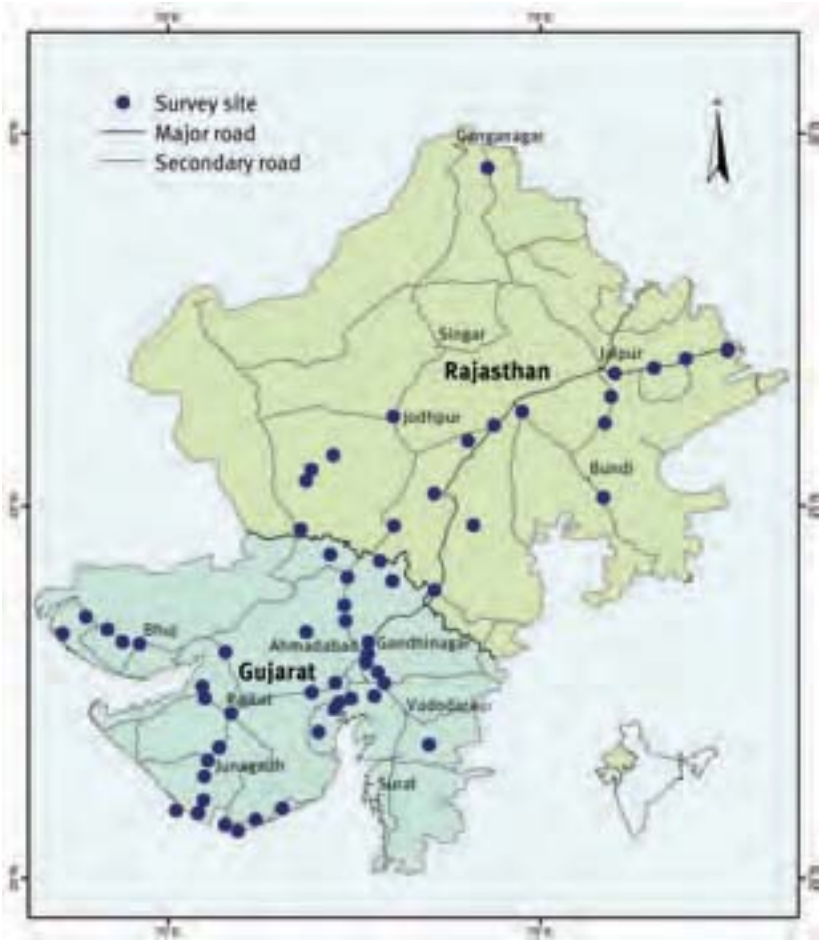

Figure 2. Survey sites in Rajasthan and Gujarat, India.

Photo 3. A new leaf-infecting rust (*Ravenelia* sp. nova) collected on prickly acacia in Gujarat, India in January 2010.

Shivas (Principal Plant Pathologist, DEEDI), this rust is a new *Ravenelia* species yet to described. This rust was also observed only on *A. nilotica* ssp. *indica* in the field.

Exclusion studies

In Gujarat and Rajasthan, exclusion studies have concluded. Plants have been harvested and various parameters recorded. Plant height, basal stem diameter, root length and above-ground biomass were lower in plants exposed to insect herbivores than in plants protected from insect herbivores, and reductions varied between 'open' and 'shade' conditions (Figure 3). In both states, insect herbivores had no effect on the number of branches or leaves per plant and below-ground biomass. In Tamil Nadu, exclusion studies are in progress.

Agent prioritisation

In southern India (Tamil Nadu and Karnataka), a leaf-webbing caterpillar (*Phycita* sp.), a babul scale (*Anomalococcus indicus*), two leaf-feeding weevils (*Dereodus denticollis* and *D. mastos*) and a rust fungus (*R. acacia-arabicae*) have been prioritised for further studies based on field host range.

Laboratory colonies of three of the prioritised insects (*A. indicus*, *Phycita* sp and *D. denticollis*) have been established at the Institute of Forest Genetics and Tree Breeding and preliminary host-specificity tests using various *Acacia* spp. native to India are in progress. Methods to infect and maintain rust infection on potted prickly acacia seedlings have been standardised.

An insect that induces shoot-tip galls, which was found only from September to November in Gujarat, was initially considered a promising agent but is not being pursued for host-specificity studies due to difficulties in collecting adults for identification and colony establishment.

Pathogenicity of the new leaf rust (*Ravenelia* sp. nova) collected recently in Gujarat has been confirmed using inoculation studies at the Arid Forest Research Institute. Preliminary host-specificity tests for the new rust are in progress.

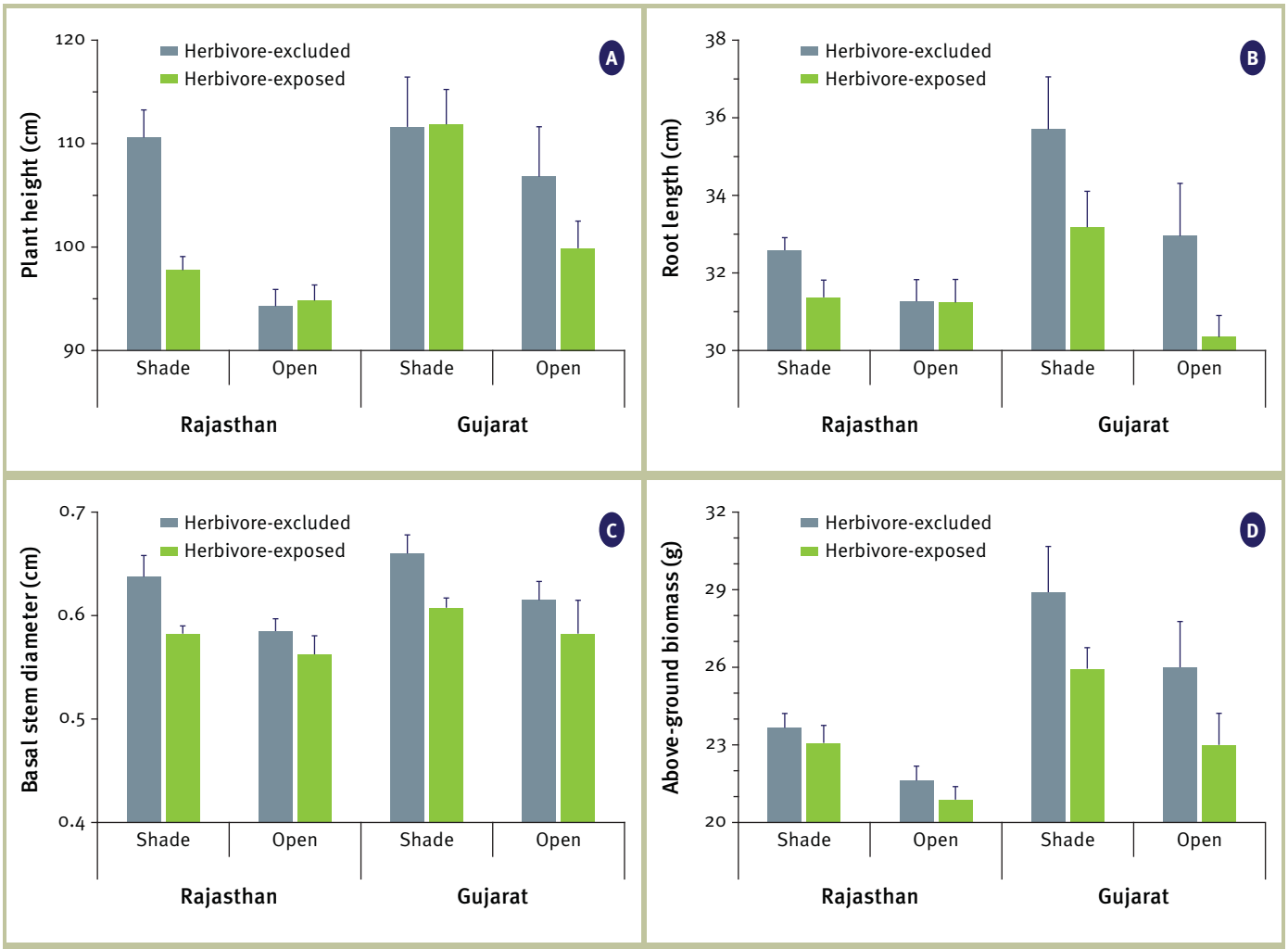

Figure 3. Impact of insect herbivores on vigour of prickly acacia seedlings over two years in north-western India.

Host-specificity tests

We have obtained approval to export prioritised agents into Australia from the Government of India (Indian Council of Forestry Research and Education).

Observations on the field host range and preliminary no-choice host-specificity tests in the lab suggest that the leaf-webber *Phycita* sp. is host-specific. During extensive quarterly field surveys at 70 sites in Tamil Nadu and Karnataka states over three years, *Phycita* sp. was observed only on *A. nilotica*. Preliminary no-choice host-specificity tests conducted in India in 2010 involving six *Acacia* species (*A. mellifera, A. ferruginea, A. auriculiformis, A. catechu, A. leucophloea* and *A. farnesiana*) and economically important plants such as mango (*Mangifera indica*) and cashew (*Anacardium occidentale*) demonstrated that *Phycita* sp. larvae collected on *A. nilotica* in Tamil Nadu could not feed or complete larval development on any species other than *A. nilotica*.

The babul scale (*A. indicus*) is a phloem feeder found on the stems and shoots of *A. nilotica*. Severe infestations cause defoliation and widespread mortality in *A. nilotica*. When heavily infested, the shoot is completely encrusted with the scale insect. During extensive quarterly field surveys at 70 sites in Tamil Nadu over the last three years, *A. indicus* was observed only on *A. nilotica*. This has been further confirmed in India by no-choice host-specificity tests in the laboratory involving various *Acacia* species (e.g. *A. mellifera, A. ferruginea, A. auriculiformis, A. catechu, A. leucophloea* and *A. farnesiana*), as well as *Piper nigrum* and *Ziziphus mauritiana*.

D. denticollis adults are leaf feeders and the larvae are root feeders. During extensive quarterly field surveys at 70 sites in Tamil Nadu over three years, *D. denticollis* was not observed on other *Acacia* species, even when these co-occurred with *A. nilotica*. This has been further confirmed in India by no-choice host-specificity tests in the laboratory involving various *Acacia* species (e.g. *A. mellifera, A. ferruginea, A. auriculiformis, A. catechu, A. leucophloea* and *A. farnesiana*).

Based on the preliminary host-specificity tests and field host range, we have obtained permits from the Australian Quarantine and Inspection Service (AQIS) and the Department of the Environment, Water, Heritage and the Arts (DEWHA) to import the leaf webber (*Phycita* sp.), the babul scale insect (*A. indicus*) and the leaf weevil (*D. denticollis*) into Australia from India for detailed host-specificity tests.

Funding in 2009–10

- MLA ($85 000)
- Land Protection Fund ($90 000)
- Queensland Government

Collaborators

- Roger Shivas, Principal Plant Pathologist (DEEDI)
- Arid Forest Research Institute, Jodhpur, Rajasthan, India
- Institute of Forest Genetics and Tree Breeding, Coimbatore, Tamil Nadu, India

More information

Key publications

Dhileepan, K. 2009. *Acacia nilotica* ssp. *indica* (L.) Willd. ex Del. (Mimosaceae). In: *Biological control of tropical weeds using arthropods*. R. Muniappan, G.V.P. Reddy and A. Raman, eds. Cambridge University Press, Cambridge. pp. 17–37.

Dhileepan, K., Lockett, C.J., Robinson, M. and Pukallus, K. 2009. Prioritising potential guilds of specialist herbivores as biological control agents for prickly acacia through simulated herbivory. *Annals of Applied Biology* 154(1): 97–105.

Dhileepan, K., Senaratne, K.A.D.W. and Raghu, S. 2006. A systematic approach to biological control agent exploration and prioritisation for prickly acacia (*Acacia nilotica* ssp. *indica*). *Australian Journal of Entomology* 45(4): 303–307.

For further information on this research project and access to key publications, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

12. Biological control of Hudson pear (*Cylindropuntia rosea*)

Project dates
October 2009 – June 2011

Project leader
Dr Bill Palmer
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Other staff in 2009–10
Peter Jones

Objectives
- Obtain permission to release the cochineal bug *Dactylopius tomentosus* as a biological control agent for Hudson pear in Australia by providing evidence of its host-specificity through laboratory experimentation within quarantine.
- Determine the effectiveness of this biotype of *D. tomentosus* against various other *Cylindropuntia* spp. found in Australia.

Rationale
Hudson pear (*Cylindropuntia rosea*) is native to Mexico. In Australia, it is found primarily in north-western New South Wales, but also occurs in Queensland. It was approved as a target for biological control by the Natural Resource Management Standing Committee (NRMSC) in 2008. Biosecurity Queensland has been contracted by Industry & Investment New South Wales to test the host-specificity of the cochineal insect *Dactylopius tomentosus* in quarantine.

Methods
Our role includes culture of the bug, care of plants and appropriate host-specificity testing to determine that the insect does not attack any native or economically desirable plant. We also evaluate the efficacy of the insect against other weedy *Cylindropuntia* spp. found in Australia. If testing determines that the insect is safe to release in Australia, the appropriate permissions will be obtained from AQIS and DEWHA to enable its release from quarantine.

Our collaborators in New South Wales source the culture and test plants, design experiments in consultation with us, arrange for mass-rearing and release of the bug in the infested areas of New South Wales and write resulting reports.

Photo 1. *C. rosea* in flower.

Progress in 2009–10
A population of *D. tomentosus* on the required host *C. rosea* was sourced by the cooperating scientists in Hidalgo, Mexico. The identity of both host and insect were confirmed by taxonomic authorities. The insect was then reared in a laboratory in Morelos, Mexico while permits were obtained for its export from Mexico and its import into quarantine in Australia.

We experienced problems in obtaining some permits and also in arranging for the material to be shipped to Australia. Eventually, we decided that the material should be hand-couriered to Australia by Dr Chavez. By the year's end, arrangements were made for the insect to be brought over in August 2010.

Funding in 2009–10
Industry & Investment New South Wales ($80 000)

Collaborators
- Royce Holtkamp (Industry & Investment New South Wales)
- Catherine Mathenge (University of Western Sydney)
- Carla Chavez Moreno (Universidad Nacional Autónoma de México, Mexico)
- Mayra Pérez and Sandi Cuen (Aridamerica AC, Mexico)
- Helmuth Zimmermann (Helmuth Zimmermann & Associates, South Africa)

More information
For further information on this research project, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

13. Biological control of mother-of-millions (*Bryophyllum* spp.)

Project dates
January 2000 – July 2011

Project leader
Dr Bill Palmer
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Other staff in 2009–10
Wilmot Senaratne

Objectives
- Achieve biological control of mother-of-millions by introducing and releasing exotic insect species or pathogens.
- Produce risk, economic, stakeholder and partner analyses for the mother-of-millions weed problem.
- Support any application under the *Biological Control Act 1987* through the various processes of the Act and determine whether the Act can be used to assist biological control projects.

Rationale
Mother-of-millions (*Bryophyllum* spp.), a native of Madagascar, is a Class 2 declared weed in Queensland. It is toxic to cattle and can have substantial economic and environmental impacts.

Surveys for potential biocontrol agents for mother-of-millions began in 2000. The weevils *Osphilia tenuipes* and *Alcidodes sedi* were studied in detail in the quarantine facility at AFRS, while preliminary studies of two further agents were undertaken in South Africa. All potential biocontrol agents for mother-of-millions had narrow host ranges but were capable of attacking very closely related, exotic, ornamental plants such as *Kalanchoe blossfeldiana* and *Echeveria* spp.

Due to potential conflicts of interest, all agents would require approval through the *Biological Control Act 1987*. When biological control targets and agents are declared under the Act, proponents are not legally liable for identified adverse effects and legal injunctions cannot be brought to prevent releases of the agent.

Methods
We study and maintain colonies of potential biological control agents in the quarantine facility of AFRS. If approval for release can be obtained, we mass-rear agents and release them throughout the range of the weed in Queensland. We then monitor the releases to determine establishment progress and any effects of the agent.

The process laid out in the *Biological Control Act 1987* involves applying to the Natural Resource Management Ministerial Council (NRMMC). If the NRMMC unanimously supports the application, a Biological Control Authority then seeks the views of all stakeholders and determines the benefits and costs of the proposed biological control. If, on balance, the benefits outweigh costs, the NRMMC may by unanimous opinion approve the declaration of target and agent organisms under the Act.

A PhD student, receiving some support and supervision from Biosecurity Queensland, studies populations of mother-of-millions in the Western Downs to determine the effects of the South African citrus thrips (*Scirtothrips aurantii*).

Progress in 2009–10
We maintained cultures of *O. tenuipes* and *A. sedi* in quarantine throughout the year. These insects remain promising biocontrol agents if they can be approved for release.

We prepared briefings for Biosecurity Queensland executive management and have supported the progression of an application for agent release through the *Biological Control Act 1987*.

The PhD student concluded her field studies of *S. aurantii* and also studied the insect on various hosts in South Africa.

Funding in 2009–10
Land Protection Fund ($80 000)

Collaborators
- Jim Thompson, Director, Biosecurity Science (Biosecurity Queensland)
- Bruce Wilson, General Manager, Invasive Plants and Animals (Biosecurity Queensland)
- Michelle Rafter, PhD student (UQ)

More information
Key publications

McLaren, D.A., Palmer, W.A. and Morfe, T.A. 2006. Costs associated with declaring organisms through the *Biological Control Act* when conflicts of interest threaten weed biological control projects. In: *Proceedings of the 15th Australian Weeds Conference*. C. Preston, J.H. Watts and N.D. Crossman, eds. Weed Management Society of South Australia, Adelaide. pp. 549–552.

Witt, A.B.R. 2004. Initial screening of the stem-boring weevil *Osphilia tenuipes*, a candidate agent for the biological control of *Bryophyllum delagoense* in Australia. *Biocontrol* 49(2): 197–209.

Witt, A.B.R., McConnachie, A.J. and Stals, R. 2004. *Alcidodes sedi* (Col.: Curculionidae), a natural enemy of *Bryophyllum delagoense* (Crassulaceae) in South Africa and a possible candidate agent for the biological control of this weed in Australia. *Biological Control* 31(3): 380–387.

Hannan-Jones, M.A. and Playford, J. 2002. The biology of Australian weeds 40. *Bryophyllum* Salisb. species. *Plant Protection Quarterly* 17(2): 42–57.

For further information on this research project and access to key publications, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

Part 2 Landscape protection and restoration

1. Biological control of cat's claw creeper (*Macfadyena unguis-cati*)

Project dates
September 2002 – June 2012

Project leader
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Other staff in 2009–10
Di Taylor, Mariano Treviño, Jayd McCarthy and Matthew Shortus

Objective
Achieve biological control of cat's claw creeper using introduced insect species.

Rationale
Cat's claw creeper (*Macfadyena unguis-cati*), an invasive liana native of Central and South America, is a major weed in coastal Queensland and New South Wales, where it poses a significant threat to biodiversity in riparian and rainforest communities. The plant is a structural parasite and produces stolons and subterranean root tubers. Biological control appears the most suitable management option for this weed. Management objectives are focused on reducing the rate of shoot growth to limit the weed's ability to climb and smother native vegetation, as well as reducing tuber biomass to minimise the tuber bank.

Methods
Native range surveys
Dr Stefan Neser of ARC-PPRI conducts surveys in Paraguay and Brazil to collect fresh specimens of the leaf-tying moth (*Hypocosmia pyrochroma*) and leaf-mining buprestid beetle (*Hylaeogena jureceki*), and also to look for new biological control agents. Any potential agents collected are maintained in quarantine at ARC-PPRI in South Africa for further testing and we import suitably host-specific agents to the AFRS quarantine facility.

Host-specificity tests
Host-specificity testing is conducted using potted test plants in a temperature controlled (22 °C to 27 °C) quarantine insectary at AFRS. We evaluate the potential host range of the leaf-mining buprestid beetle (*H. jureceki*) on the basis of larval survival and development, adult feeding and survival, and oviposition preference using choice and no-choice tests involving 38 plant species in 12 families.

Field release and monitoring
We mass-rear and field-release two biological control agents, the leaf-sucking tingid (*Carvalhotingis visenda*) and leaf-tying moth (*H. pyrochroma*), in partnership with community groups. We use a simple and cost-effective method to mass-rear the leaf-tying moth by replacing potted plants with field-collected cut foliage to allow greater numbers of insects to be released in the field. After field release we conduct recovery surveys to determine the field establishment status of *C. visenda*. At all release sites, we spend 20 minutes visually examining cat's claw creeper plants and recording the incidence and abundance of *C. visenda* eggs, nymphs and adults.

Thermal tolerance studies
We study the effects of constant temperatures (15 °C to 40 °C) on the survival and development of the leaf-tying moth (*H. pyrochroma*) in temperature controlled cabinets.

Ecological studies
Two morphologically and phenologically distinct varieties of cat's claw creeper occur in Australia—a short-pod variety that is widespread through Queensland and New South Wales, and a long-pod variety restricted to a few sites in south-eastern Queensland. We study the leaf (e.g. leaf area, leaf biomass, leaf thickness and chlorophyll content), flower (e.g. colour), seed pod (e.g. pod length, pod width, pod biomass, and number of seeds per pod) and seed (e.g. seed size and seed biomass) traits as well as flowering and podding phenology of the two varieties at two sites (Oxley and Carindale) where they co-occur.

We also study the growth of the two varieties at four field sites (two riparian and two non-riparian) in south-eastern Queensland. At each site, we plant similar sized long-pod and short-pod cat's claw creeper seedlings (20 per variety) and install a trellis for the vines to grow on. We record various plant growth parameters (shoot length, number of shoots, basal stem diameter, number of leaves, etc.) at the beginning of the trial and at quarterly intervals. At the end of the trial (22 months after commencement), we remove all plants from the soil (along with the subterranean tubers and roots) and record various plant parameters including the leaf, stem and root biomass.

Progress in 2009–10
Native range surveys
Field surveys were conducted in northern Paraguay and southern Brazil in 2009. Previously tested agents, including the leaf-sucking tingid (*C. visenda*), leaf-tying moth (*H. pyrochroma*), leaf-mining buprestid beetle (*H. jureceki*), leaf-feeding tortoise beetle (*Charidotis auroguttata*) and seed-feeding weevil (*Apteromechus notatus*) were re-collected from climatically suitable areas to enrich the existing colonies of these insects in South Africa and Australia. In addition, Dr Neser documented several new insects on cat's claw creeper:

- A cicadellid bug known to occur only on cat's claw creeper in Brazil has been identified as *Neocrassana undata*. The cicadellid prefers young plants, and in the field appears to be restricted to leaves growing at ground level. Feeding by both adults and nymphs causes leaf deformation and necrotic lesions.
- An unidentified tingid (not *Carvalhotingis*) feeding on cat's claw creeper leaves was collected from Foz do Iguazu in Brazil. The tingid is being identified. This is the third tingid species recorded on cat's claw creeper in its native range.
- In Brazil, a yet-to-be-identified cecidomyiid fly induced elongated galls (swellings) on the shoots, causing shoot

dieback. Each gall usually contained one larva, but many larvae were observed in compound galls. The mature larvae pupate within the gall. This species merits further study as it is likely to be host-specific and sufficiently damaging.

In Brazil, the seed-feeding weevil (*A. notatus*) has been observed in large numbers destroying up to 80% of the seeds found within developing pods, thereby reducing seed rain. Adult weevils are long-lived and lay eggs on green or immature pods. Hatching larvae burrow into the pod and feed on numerous seeds before pupating. After overwintering as either pupae or newly emerged adults within the pod, the next generation of adults emerges in spring to coincide with flowering and early pod production. This life history, however, presents significant challenges to rearing and host-specificity testing in quarantine.

Host-specificity tests

After obtaining permits from AQIS and DEWHA to import the leaf-mining buprestid beetle (*H. jureceki*) from South Africa into Australia for detailed host-specificity tests, we received two shipments into the AFRS quarantine facility in late 2009. The first shipment died out in the high security section. For this reason newly emerged adults from the second shipment were moved to the standard security section where they have thrived. Adults feed and lay eggs and the emerging larvae feed and complete development (Photo 1) on both the long-pod and short-pod varieties of cat's claw creeper.

Photo 1. *H. jureceki* larval feeding damage and pupation on a cat's claw creeper leaf.

Photo 2. Field recovery of *H. pyrochroma* larvae at the Oxley release site.

Host testing began in January 2010. To date, 24 test species have been subjected to no-choice adult feeding. Oviposition trials and testing of another four species will be finished in the very near future. Of the remaining 10 species, testing has begun on four species. Limited exploratory feeding has been detected on a few test species, but none has been capable of supporting development of the insect. Six more test species are yet to be tested.

Field release and monitoring

Mass-rearing and field releases of the leaf-sucking tingid (*C. visenda*) commenced in May 2007 and since then we have released more than half a million individuals at 72 sites in Queensland and New South Wales. In addition, community groups released over 11 000 tingid-infested potted cat's claw creeper plants at 63 sites in Queensland. Field establishment of the tingid was evident at 80% of the release sites after three years. The tingid established on both the long-pod and short-pod cat's claw creeper varieties. Better establishment occurred at sites that received more than two field releases (83%) than at sites that received two or fewer releases (73%); and also at sites that received more than 5000 individuals (82%) than at sites that received less than 5000 individuals (68%). In the field, the tingid spread slowly (5.4 m $year^{-1}$). The spread was mostly horizontal along the ground level infestations and, less often, vertically on the plants climbing on trees. The maximum distance of tingid incidence away from the initial release points ranged from 6 m to around 1 km. The *C. visenda* release program has now ceased.

The leaf-tying moth (*H. pyrochroma*) was approved for field release in 2008, and since then field releases as larvae and adults have been made at 17 sites in south-eastern Queensland and northern New South Wales. An improved laboratory rearing method that replaces potted plants with corrugated paper for oviposition, cut foliage for larval feeding and sterilised sand for pupation in temperature controlled rearing cages has resulted in the field release of large numbers of larvae and adults. Although larvae have been recovered from four of the release sites (Photo 2), it is too early to determine the moth's field establishment status in

Australia. Field releases of *H. pyrochroma* will continue for one more year.

Thermal tolerance studies

Oviposition occurred and larval and pupal development was completed between 20 °C and 30 °C; the optimum temperature was about 25 °C. However, egg development and hatching occurred over a wide temperature range (15 °C to 35 °C). Pupal duration ranged from 14 days at 30 °C to 177 days at 20 °C and the extended pupal period at or below 20 °C and above 35 °C was due to pupal diapause.

Ecological studies

The long-pod variety has significantly larger leaves, larger pods and a larger number of seeds per pod than the short-pod variety (Photo 3). The short-pod variety has slightly wider pods and thicker leaves than the long-pod variety (Photo 3). Both varieties have a yellow trumpet-shaped flower, but the flower of the long-pod variety has a deeper hue of yellow than the short-pod flower (Photo 3). The fruits of the short-pod variety mature in late summer to early autumn, while the fruits of the long-pod variety mature in late winter to early spring.

Results from the field studies suggest that long-pod plants are more vigorous than short-pod plants, producing 40% more leaves. Above-ground biomass and total biomass were significantly greater for long-pod plants than short-pod plants at all sites (Figure 1). Long-pod plants also produced more below-ground biomass, but the difference was not statistically significant. Site had a significant effect on the amount of biomass produced. Plants grown at the two non-riparian sites (Carindale and Bardon) produced significantly more biomass than those planted at one of the riparian sites (Nerang), which experienced two flood events during the study period (Figure 1). Biomass allocation differed significantly between the two varieties (Figure 2). Leaf mass ratio and stem mass ratio were higher and root mass ratio lower for long-pod plants than short-pod plants. Site did not significantly affect stem mass ratio or root mass ratio, but did affect leaf mass ratio.

Funding in 2009–10

- Land Protection Fund ($126 000)
- Queensland Government (Blueprint for the Bush)

Collaborators

- Stefan Neser and Anthony King (ARC-PPRI, South Africa)
- Tanya Scharaschkin (Faculty of Science and Technology, QUT)
- DERM/QPWS
- Environmental Training and Employment Inc, New South Wales
- Local government and community groups across south-eastern and central Queensland

More information

Key publications

Dhileepan, K., Bayliss, D. and Treviño, M. 2010. Thermal tolerance and potential distribution of *Carvalhotingis visenda* (Hemiptera: Tingidae), a biological control agent for cat's claw creeper, *Macfadyena unguis-cati* (Bignoniaceae). *Bulletin of Entomological Research* 100(2): 159–166.

Photo 3. Differences in the leaf shape and size (a & b), flower colour (c) and pod length (d) between long-pod and short-pod varieties of *Macfadyena unguis-cati*.

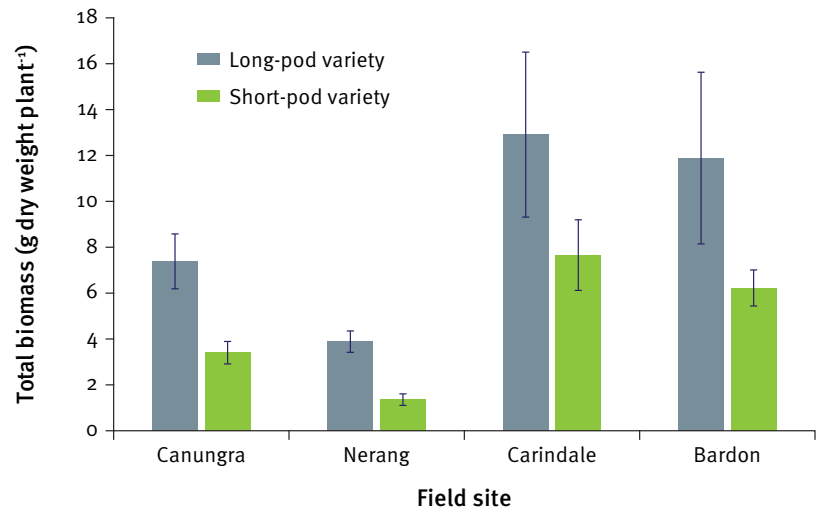

Figure 1. Total biomass for long-pod and short-pod plants at four field sites in south-eastern Queensland.

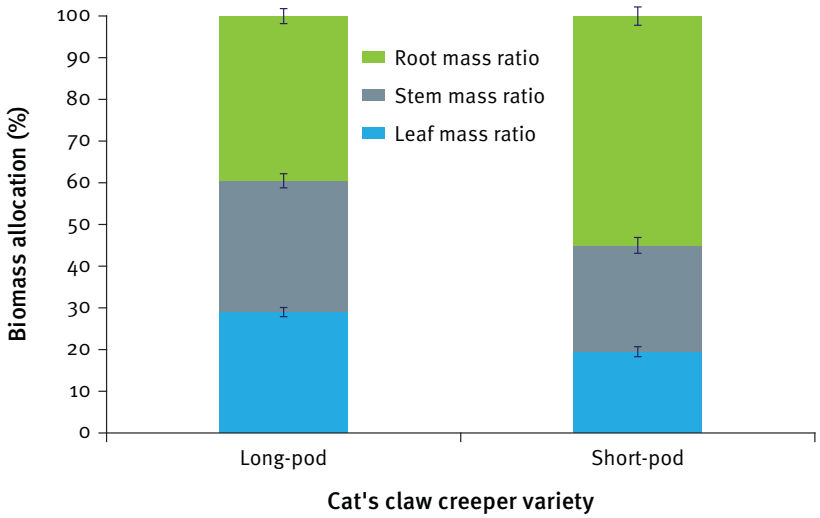

Figure 2. Average biomass allocation for long-pod and short-pod plants across four field sites in south-eastern Queensland.

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Conrad, K.A. and Dhileepan, K. 2007. Pre-release evaluation of the efficacy of the leaf-sucking bug *Carvalhotingis visenda* (Heteroptera: Tingidae) as a biological control agent for cat's claw creeper *Macfadyena unguis-cati* (Bignoniaceae). *Biocontrol Science and Technology* 17(3): 303–311.

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For further information on this research project and access to key publications, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

2. Biological control of Madeira vine (*Anredera cordifolia*)

Project dates
June 2007 – May 2011

Project leader
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Other staff in 2009–10
Wilmot Senaratne, Liz Snow and Peter Jones

Objective
Achieve biological control of Madeira vine by introducing and releasing exotic insect species or pathogens.

Rationale
Madeira vine (*Anredera cordifolia*) is a South American plant that has become an increasingly important environmental weed in eastern Australia. This vigorous perennial climber or scrambling shrub forms dense mats that cover trees and shrubs and it is now a problem weed in rainforests, riparian lands, bushland remnants and conservation areas. It is the only naturalised plant in the family Basellaceae in Australia, so there is a good chance that biological control agents found in its native range would be sufficiently host-specific for safe release. However, one exotic species from this family, Ceylon spinach (*Basella alba*), is grown in gardens in south-eastern Queensland. South African scientists led by Dr Stefan Neser have identified some promising agents, which were made available to this project.

Methods
Surveys for suitable biological control agents of Madeira vine are conducted by Dr Stefan Neser from ARC-PPRI in Argentina and Brazil. We import those insects considered suitable, mainly as a result of host testing undertaken in South Africa, into the quarantine facilities at AFRS for final host-specificity testing and biology studies. We also develop climate matching models for prospective agents.

We submit applications to have Madeira vine approved as a target for biological control by the NRMSC and to have any suitable agents approved for release by AQIS and DEWHA. Approved agents are then mass-reared for distribution to climatically favourable areas. Following release, we monitor establishment progress and evaluate any effects of the agents.

Progress in 2009–10
This year, we continued our work on the study of the leaf beetle, *Plectonycha correntina*, which had been found in the native range of the plant and recognised as a potential biological control agent after preliminary host testing in Argentina. Appropriate tests and studies were undertaken at AFRS to determine whether *P. correntina* is safe to release in Australia for the biological control of Madeira vine.

A host test list of 37 plant species was compiled using the centrifugal phylogenetic method after first circulating a provisional list to representatives of all state governments, Biosecurity Australia, DEWHA and CSIRO. A significant feature of the testing design was that Basellaceae contains no native Australian species and Madeira vine is the only member of the family naturalised in Australia.

All plants on the host test list were used for no-choice tests using both adults and eggs of *P. correntina*. These tests established that the insect could complete its life cycle only on Madeira vine or *Basella alba,* also a member of Basellaceae.

Further testing on Madeira vine and *B. alba* established that the latter is a much inferior host to Madeira vine and four attempts to establish a culture on *B. alba* all failed at the end of the first generation. The experimental evidence suggests that *B. alba*, which is a minor, non-commercial garden vegetable, might be subjected to some feeding should it be growing near Madeira vine infested with *P. correntina* but this damage would be of little consequence.

The release of *P. correntina* for the biological control of Madeira vine was therefore recommended in a report submitted to AQIS and DEWHA in December 2009. The case for this insect was the first to be processed through Biosecurity Australia's new protocols for biological control agents.

Funding in 2009–10
- Land Protection Fund ($138 000)
- Queensland Government

Collaborators
Stefan Neser and Liame van der Westhuizen (ARC-PPRI, South Africa)

More information
Key publications

Cagnotti, C., McKay, F. and Gandolfo, D. 2007. Biology and host specificity of *Plectonycha correntina* Lacordaire (Chrysomelidae), a candidate for the biological control of *Anredera cordifolia* (Tenore) Steenis (Basellaceae). *African Entomology* 15(2): 300–309.

Vivian-Smith, G., Lawson, B.E., Turnbull, I. and Downey, P.O. 2007. The biology of Australian weeds 46. *Anredera cordifolia* (Ten.) Steenis. *Plant Protection Quarterly* 22(1): 2–10.

van der Westhuizen, L. 2006. *The evaluation of Phenrica sp. 2 (Coleoptera: Chrysomelidae: Alticinae), as a possible biological control agent for Madeira vine, Andredera cordifolia (Ten.) Steenis in South Africa*. MSc thesis. Department of Zoology and Entomology, Rhodes University. South Africa.

For further information on this research project and access to key publications, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

3. Biological control of lantana (*Lantana camara*)

Project dates
Ongoing

Project leaders
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Other staff in 2009–10
Natasha Riding, Kirsty Gough and Kelli Pukallus

Objective
Import, evaluate host-specificity, mass-rear, field-release and monitor biological control agents for lantana.

Rationale
Lantana (*Lantana camara*) is native to tropical America and was first introduced into Australia in the mid 1800s. It has since become a major weed of agricultural and natural ecosystems. In grazing lands, lantana dominates preferred pasture species, thereby decreasing productivity, and also interferes with mustering. Some varieties are toxic to livestock. It is estimated to cost the grazing industry over $100 million a year in lost production and control costs. Lantana can become the dominant understorey species in natural ecosystems, blocking succession and decreasing biodiversity. Lantana is a Class 3 declared weed in Queensland and has been the target of biocontrol programs since 1914. Introducing new and more effective biocontrol agents further enhances control of lantana and reduces dependency on chemicals and other control methods.

Methods
We contract entomologists and pathologists in Mexico, South Africa and Europe to locate and study the biology, phenotype preference and preliminary host-specificity of potential biocontrol agents prior to their introduction into quarantine in Australia.

We then determine the host-specificity of imported organisms. Any agents approved for field release are mass-reared and released in appropriate areas with the help of Biosecurity Officers, DERM/QPWS officers and local government weed officers.

Progress in 2009–10
The lantana mirid (*Falconia intermedia*) continues to spread on the Atherton Tableland. It is found at sites from Ravenshoe to Yungaburra, as well as around Julatten, causing seasonal defoliation.

Field releases of the lantana rust (*Prospodium tuberculatum*) have ceased. Populations fluctuate with rain, but the rust appears widespread from Bundaberg and Fraser Island south to Port Macquarie in New South Wales. It is also widespread on the Atherton Tableland, with smaller populations around Mt Fox and Paluma.

The lantana herringbone leaf-mining fly (*Ophiomyia camarae*) continues to be mass-reared at TWRC for field release. However, field releases from AFRS have stopped. The fly appears to be more suited to the tropical regions than south-eastern Queensland. To date, we have released over 100 000 individuals at over 140 sites in north Queensland. Leaf mines have been found at over 130 sites and up to 50 km away from some release sites. There has been some defoliation of lantana bushes around Cooktown and at one site near Ayr.

In south-eastern Queensland monitoring continues and has shown that leaf mines now occur at only three sites, but the insect is slowly spreading. Apart from the cooler conditions in south-eastern Queensland, the fly has to compete with other biocontrol agents, particularly *Calycomyza lantanae* and *Uroplata girardi*.

As part of a requirement by AQIS, we contracted ARC-PPRI to host-test a further four plant species against the lantana budmite (*Aceria lantanae*). We have now received the final report and the studies found a few small galls began to develop on *Lippia alba* but did not develop further, while no damage to any of the other four test plants occurred. A report will be

Photo 1. Damage by *Falconia intermedia* on the Atherton Tablelands. (Photo courtesy of Sid Clayton.)

Photo 2. Lantana leaves with mines of *O. camarae*, *C. lantanae* and *U. girardi* at AFRS, Sherwood.

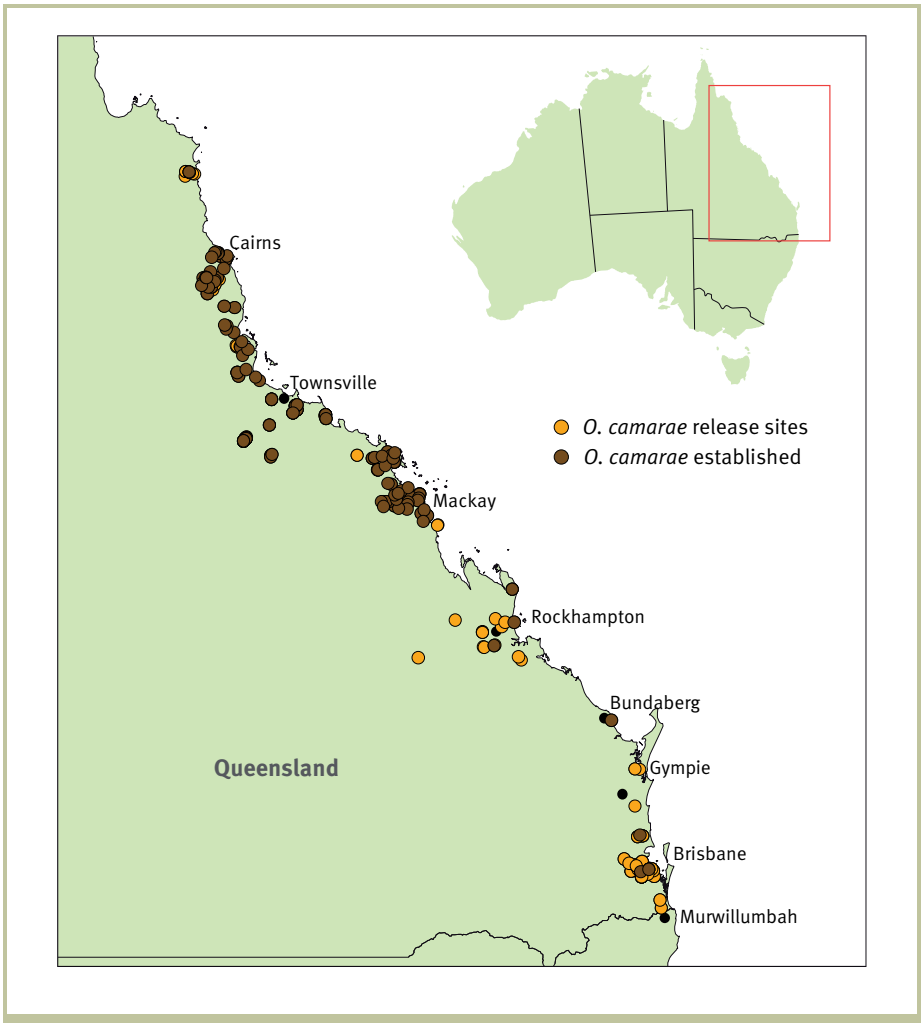

Figure 1. Current distribution of *O. camarae* in Queensland.

submitted to AQIS and DEWHA to apply for the budmite's field release.

We contracted CABI Europe–UK to study the biology, biotype preference and host-specificity of the pathogen *Puccinia lantanae*. Initial investigations found some infection on the native *Verbena officinalis* var. *africana* (previously reported as *V. gaudichaudii*) as well as the weed *Phyla canescens* and a draft report has been received. Following discussions with various researchers, including some from CSIRO, recommendations for further testing were sent to CABI for consideration.

DNA studies by CSIRO Plant Industry are continuing. Results to date suggest that lantana in Australia is just one large highly variable group or hybrid swarm and the tests conducted cannot differentiate the samples into different taxa. The studies have shown that lantana in Australia is most closely related to that in Venezuela and the Caribbean. Considering that some biocontrol agents show preferences for different lantana varieties in Australia, and that different varieties have different levels of toxicity, further work is required to tease the group apart.

Funding in 2009–10

Land Protection Fund ($144 000)

Collaborators

- ARC-PPRI, South Africa
- CABI Europe–UK, United Kingdom
- Centre for Origin Research, United States
- CSIRO Plant Industry
- CSIRO Entomology
- DERM
- Department of Environment, Climate Change and Water, New South Wales
- Industry & Investment New South Wales
- UQ
- Local governments in Queensland and New South Wales

More information

Key publications

Day, M.D. and Zalucki, M.P. 2009. *Lantana camara* Linn. (Verbenaceae). In: *Biological control of tropical weeds using arthropods*. R. Muniappan, G.V.P. Reddy and A. Raman, eds. Cambridge University Press, Cambridge. pp. 211–246.

Day, M.D., Riding, N. and Chamberlain, A. 2009. Biology and host range of *Ophiomyia camarae* Spencer (Diptera: Agromyzidae), a potential biocontrol agent for *Lantana* spp. (Verbenaceae) in Australia. *Biocontrol Science and Technology* 19(6): 627–637.

Zalucki, M.P., Day, M.D. and Playford, J. 2007. Will biological control of *Lantana camara* ever succeed? Patterns, processes & prospects. *Biological Control* 42(3): 251–261.

Day, M.D., Broughton, S. and Hannan-Jones, M.A. 2003. Current distribution and status of *Lantana camara* and its biological control agents in Australia, with recommendations for further biocontrol introductions into other countries. *Biocontrol News and Information* 24(3): 63N–76N.

Day, M.D., Wiley, C.J., Playford, J. and Zalucki, M.P. 2003. *Lantana: current management status and future prospects*. ACIAR, Canberra. 128 pp.

For further information on this research project and access to key publications, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

4. Biological control of mikania vine (*Mikania micrantha*) in Papua New Guinea and Fiji

Project dates

July 2006 – June 2011

Project leader

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Objectives

Introduce and establish biocontrol agents for mikania vine in Fiji and Papua New Guinea to:

- reduce the impact of the weed to small block holders and plantation owners in areas where it is a problem
- reduce the seed load and thus the possibility of further spread into northern Australia
- establish successful biocontrol methods for use in northern Australia if required
- promote biocontrol as a safe and successful weed control method
- train scientists in Fiji and Papua New Guinea in biocontrol methods.

Rationale

Mikania vine (*Mikania micrantha*) is native to tropical America and is now a major weed throughout the South Pacific and South-East Asia. The plant is a perennial vine that grows extremely rapidly, about 1 metre per month, smothering crops and plantation trees. In Queensland, mikania vine is currently confined to the wet tropics region, where it has the potential to impact significantly on the sugar, horticultural, beef and tourist industries and to spread throughout northern Australia. Mikania vine is a Class 1 declared weed in Queensland and is the target of a national cost-share eradication program. Biological control of mikania vine in the South Pacific was first attempted in the 1970s. However, the agent failed to establish. This project aims to introduce two butterfly species (*Actinote anteas* and *A. pyrrha thalia*) from Indonesia and the mikania rust (*Puccinia spegazzinii*) into both Fiji and Papua New Guinea.

Photo 1. Researchers Annastasia Kawi (left) and Kiteni Kurika from the National Agricultural Research Institute, Papua New Guinea, checking *P. spegazzinii* in the field at Takubar, Papua New Guinea.

Photo 2. Rust pustules on mikania vine growing over bananas at Rapito, Papua New Guinea.

Better control of the weed in neighbouring countries such as Papua New Guinea and Fiji will in turn reduce the risk of further spread into Queensland. A greater understanding of mikania vine and its biocontrol agents will also boost the state's capacity to respond to an incursion if the eradication program is unsuccessful.

Methods

Suitable agents are selected based on results of host-specificity testing and field observations in other countries. We send information on the agents' life histories and host ranges to our collaborators in Fiji and Papua New Guinea, and request import permits. For the mikania butterflies (*A. anteas* and *A. thalia pyrrha*) additional host testing is conducted in Fiji prior to field release. For the mikania rust (*P. spegazzinii*), CABI Europe–UK conducts additional host

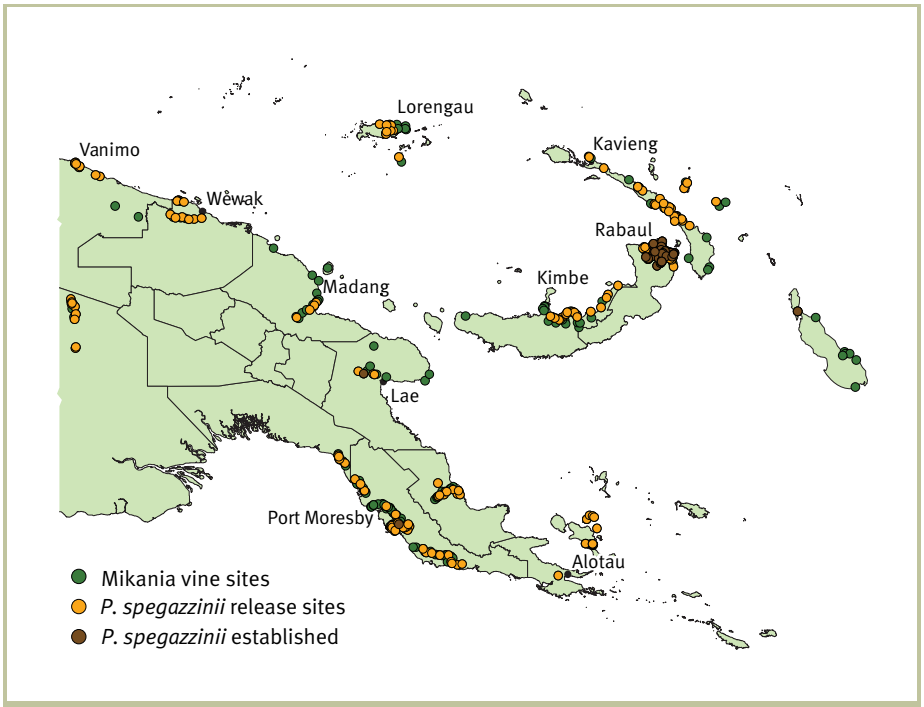

Figure 1. Current distribution of mikania vine and *P. spegazzinii* in Papua New Guinea.

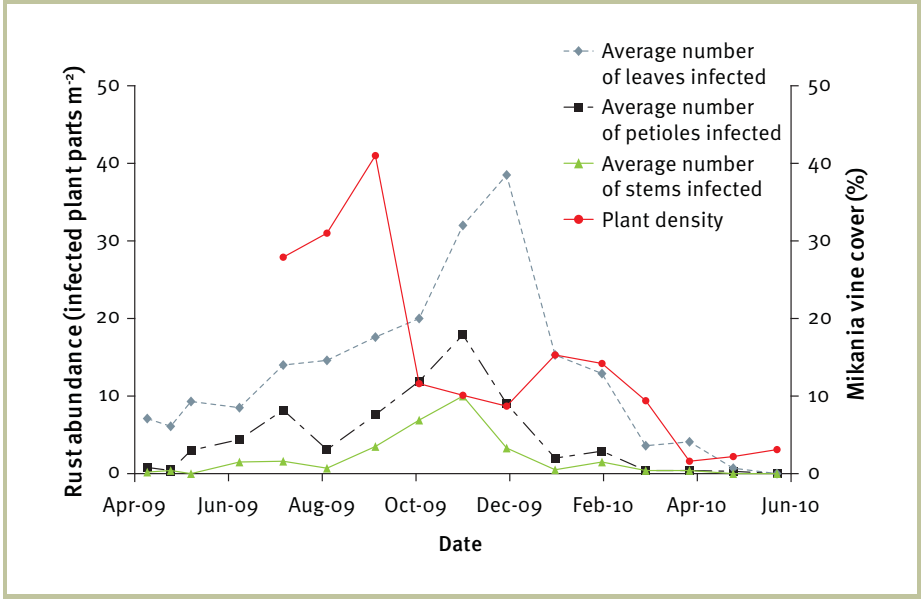

Figure 2. Effect of *P. spegazzinii* on mikania vine cover in an experimental plot at Kerevat, Papua New Guinea.

testing. We submit reports on the host testing of the agents to quarantine authorities in Fiji and Papua New Guinea. On approval, suitable agents are reared for release in both countries.

We field-release agents throughout areas of Fiji and Papua New Guinea where mikania vine is a problem. Provincial staff assist in the release of agents as part of their training in biocontrol activities. We also set up programs for monitoring plant density and spread, as well as agent establishment, population increase, spread and impact on mikania vine.

Progress in 2009–10

Mass-rearing and field release of *P.spegazzinii* in both Fiji and Papua New Guinea continued throughout 2009–10. In Papua New Guinea, the rust has been released at over 400 sites in all 15 provinces in which mikania vine is confirmed. Pustules have persisted on field plants at 68 sites in four provinces and some pustules have been found over 7 km from point of release after 12 months. It is still too early, or sites are too distant, to confirm establishment at many of the other sites.

Field monitoring of several release sites around the research station at Kerevat found that the rust is having a severe impact on mikania vine. At one plot the rust suppressed the growth of mikania vine, allowing other plants to smother the plant and reducing its cover substantially.

Funding in 2009–10

ACIAR ($71 000)

Collaborators

- ACIAR
- Secretariat of the Pacific Community
- Ministry of Primary Industries, Fiji
- National Agricultural Research Institute, Papua New Guinea
- Cocoa and Coconut Institute, Papua New Guinea
- Papua New Guinea Oil Palm Research Association
- CABI Europe–UK, United Kingdom
- Roch Desmier de Chenon, Consultant, Indonesia

More information

Key publications

Orapa, W., Day, M. and Ellison, C. 2008. New efforts at biological control of *Mikania micrantha* H.B.K. (Asteraceae) in Papua New Guinea and Fiji. In: *Proceedings of the Australia and New Zealand IOBC Biocontrol Conference*. Sydney. p. 45.

Pene, S., Orapa, W. and Day, M. 2007. First fungal pathogen to be utilized for weed biocontrol in Fiji and Papua New Guinea. *Biocontrol News and Information* 28(3): 55N–56N.

For further information on this research project and access to key publications, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

5. Weed eradication and containment: feasibility and program evaluation

Project dates

July 2003 – June 2013

Project leader

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Other staff in 2009–10

Simon Brooks and Shane Campbell

Objectives

- Provide a scientifically-based rationale for decisions about the eradication of weed incursions.
- Refine eradication methods by using ecological information.
- Monitor selected eradication programs and document associated costs.
- Develop criteria to assess the progress of eradication.

Rationale

Early intervention is the most cost-effective means for preventing weed incursions from rapidly expanding. Strategies to achieve this aim range from eradication (where the objective is to drive the incursion to extinction) to containment (which may vary from absolute to degrees of slowing its spread). Ongoing eradication and containment feasibility work should contribute to management decisions. To make informed decisions it is essential to gather case-study data to determine to what degree management objectives are achieved and assess progress towards eradication.

Methods

We develop measures for the evaluation of eradication progress with regard to the delimitation (determining the extent of the incursion) and extirpation (local extinction) criteria.

We also develop dynamic models that provide estimations of eradication program duration (and total program costs when economic data are available). The most recent modelling approach is built upon relationships between the following functions:

- time-related detection of new infested area
- rates of progression of infestations from the active to the monitoring stage
- rates of reversion of infestations from the monitoring to the active stage
- time since last detection for all infestations.

We collate data on eradication resources and progress for each infestation of clidemia (*Clidemia hirta*), limnocharis (*Limnocharis flava*), miconia (*Miconia calvescens*, *M. nervosa* and *M. racemosa*), mikania vine (*Mikania micrantha*)—under the National Four Tropical Weeds Eradication Program—and Siam weed (*Chromolaena odorata*) in Queensland. Data include method of detection, discovery over time, trends in infested areas, population decline and time since last detection.

Ecological studies of Class 1 weed eradication targets are now reported under the project '2.6 Ecology and control of national weed eradication targets' on page 43.

Progress in 2009–10

'Four tropical weeds' database

Information has been collated to publish the number, type, extent and status of *M. calvescens* locations in Australia. Of the 57 known locations in 2009, 29 show evidence of naturalisation. Three of the naturalised occurrences have transitioned to a monitoring phase while the remaining (26) infestations are in an active control phase through ongoing recruitment from a persistent seed bank.

Biosecurity Queensland scientists co-authored a paper with economic modellers from the University of New England (Hester *et al*. 2010) which provided an economic analysis of the eradication activities at the 'El Arish' *M. calvescens* infestation. This paper used information on the biology of the species to produce a stage matrix of the population and combined the population model with search theory, economic data and predictive modelling to estimate the cost and probability of eradication. Eradication is a long-term proposition due to a persistent seed bank, but the projected annual resources required to achieve eradication were only slightly higher than the actual resources allocated to this infestation between 2004 and 2007.

Modelling duration and cost of weed eradication programs

In the past year, we have simplified the model by removing the relationship that predicts new infested area. This modification has been undertaken because such predictions are difficult—particularly during the early stages of an eradication program—and are not very meaningful in the absence of information on search effort. It is a simple matter to re-run the model when new area is detected. Instead, we have extended application of the model by generating 'isoquants' which describe combinations of progression factors and reversion coefficients that will allow eradication to be achieved within specified timeframes (Figure 1).

Application of the model to the Siam weed (*C. odorata*) eradication program suggests that this weed could theoretically be eradicated within 21 years, but none of the field data collected up to 2008 indicate that eradication could be achieved even within 60 years, owing to the exceedingly low rates of progression observed. For eradication to occur within this longer timeframe, a value for the progression factor of at least 0.2 would be required (Figure 1). Overall, program data suggest that the critical process requiring improvement in the Siam weed eradication program is transition from the active to the monitoring phase. Historically, very low rates of transition have been a reflection of inconsistent visits to some infestations and difficulties in the timely control of others. Under these circumstances plants have been able to produce seed and replenish the soil seed bank. This is a situation that should be rectified by the recent substantial increase in investment in this national cost-share eradication program.

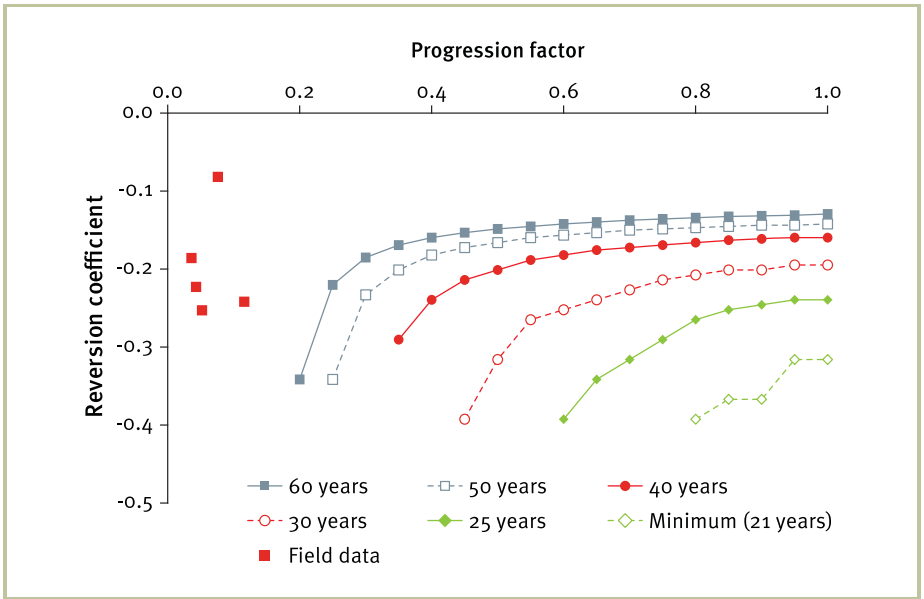

Figure 1. Isoquants demonstrating the combinations of progression factors and reversion coefficients that will allow eradication of Siam weed within various specified timeframes. The minimum possible time to eradication (open diamonds) is 21 years. Each isoquant denotes the upper limit of a parameter space allowing eradication within the respective timeframe. Red squares represent values derived from the Siam weed database for different years of the eradication program (2004–2008).

Funding in 2009–10

Queensland Government

Collaborators

- Oscar Cacho and Susie Hester (University of New England)
- Biosecurity Queensland officers based at South Johnstone and local government pest management officers provided data for eradication case studies.

More information

Key publications

Brooks, S.J., Panetta, F.D. and Sydes, T.A. 2009. Progress towards the eradication of three melastome shrub species from northern Australian rainforests. *Plant Protection Quarterly* 24(2): 71–78.

Fox, J.C., Buckley, Y.M., Panetta, F.D., Bourgoin, J. and Pullar, D. 2009. Surveillance protocols for management of invasive plants: modelling Chilean needle grass (*Nassella neesiana*) in Australia. *Diversity and Distributions* 15(4): 577–589.

Hester, S.M., Brooks, S.J., Cacho, O.J. and Panetta, F.D. 2010. Applying a simulation model to the management of an infestation of *Miconia calvescens* in the wet tropics of Australia. *Weed Research* 50(3): 269–279.

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Panetta, F.D. 2009. Weed eradication: an economic perspective. *Invasive Plant Science and Management* 2(4): 360–368.

Brooks, S.J., Panetta, F.D. and Galway, K.E. 2008. Progress towards the eradication of mikania vine (*Mikania micrantha*) and limnocharis (*Limnocharis flava*) in northern Australia. *Invasive Plant Science and Management* 1(3): 296–303.

Long, R.L., Panetta, F.D., Steadman, K.J., Probert, R., Bekker, R., Brooks, S.J. and Adkins, S.W. 2008. Seed persistence in the field may be predicted by laboratory-controlled aging. *Weed Science* 56(4): 523–528.

Panetta, F.D. 2007. Evaluation of weed eradication programs: containment and extirpation. *Diversity and Distributions* 13(1): 33–41.

Panetta, F.D. and Lawes, R. 2007. Evaluation of the Australian branched broomrape (*Orobanche ramosa*) eradication program. *Weed Science* 55(6): 644–651.

Regan, T.J., McCarthy, M.A., Baxter, P.W.J., Panetta, F.D. and Possingham, H.P. 2006. Optimal eradication: when to stop looking for an invasive plant. *Ecology Letters* 9(7): 759–766.

Panetta, F.D. and Lawes, R. 2005. Evaluation of weed eradication programs: the delimitation of extent. *Diversity and Distributions* 11(5): 435–442.

For further information on this research project and access to key publications, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

6. Ecology and control of national weed eradication targets

Project dates

July 2008 – June 2013

Project leader

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Other staff in 2009–10

Shane Campbell, Wayne Vogler, Kirsty Gough, Stephen Setter, Katie Patane, Christina Lockett and Sharon Rossow

Objectives

- Investigate key ecological attributes influencing the eradication of species targeted by national cost-share eradication programs.
- Refine eradication methods by using ecological information.
- Investigate alternative control methods for remote Siam weed infestations in the seasonally dry tropics.

Rationale

Siam weed (*Chromolaena odorata*) is a Class 1 declared weed in Queensland and has been the target of a national cost-share eradication program since its discovery in the wet tropics region of north Queensland in 1994. It has also since been found in the upper Herbert River catchment (1997) and in the upper Ross River and Black River catchments west of Townsville (2003).

The National Four Tropical Weeds Eradication Program commenced in 2003, targeting four genera of Class 1 weeds (*Clidemia hirta, Limnocharis flava, Miconia calvescens, M. nervosa, M. racemosa* and *Mikania micrantha*), which are located primarily on the wet tropics coast of Queensland.

These eradication programs will only be successful if field crews can locate all individuals of each species, apply effective control measures, prevent new seed production and monitor infestations until the seed bank is exhausted. To address queries from the eradication programs, our research concentrates on key biological parameters (soil seed bank persistence, age to maturity, flowering behaviour, seed production and dispersal vectors and barriers) and on effective control methods for each species.

Methods

Specific questions investigated by this project and the trials to address them are outlined below:

Are the key Siam weed biological characteristics of age to maturity and seed longevity the same in seasonally drier, warmer areas as they are along the wet tropics coast?

- Siam weed seeds sourced from infestations in the wet and dry tropics are germinated in the quarantine laboratories at the Centre for Wet Tropics Agriculture (CWTA) and TWRC and seedlings planted in pots at monthly intervals for one year. We collect data on growth rates and flowering behaviour and the plants are destructively harvested as they mature.
- We bury fresh Siam weed seed from an infestation near Townsville in permeable mesh packets to investigate the effects of time, grass cover, soil type and burial depth in a dry tropics environment at TWRC. Packets are retrieved every 6–12 months until no viable seed is recovered. Previous research has shown that viable seed is exhausted 7 years after burial in a wet tropics environment.

Can larger Siam weed plants be controlled by repeated burning and how do repeat fires influence the soil seed bank?

- We maintain monitoring plots within a large Townsville Siam weed infestation and subject them to repeated controlled burns. Pre-burn data collected include plant size, fuel loads, soil seed banks and soil moisture levels. Post-burn assessments include fire damage and mortality of Siam weed, sizes of soil seed banks and seedling recruitment.

Can Siam weed be effectively treated with a low volume, high concentration herbicide application through a splatter (gas) gun?

- Some infestations in remote or rugged country cannot be treated with high volume foliar herbicide applications and there has been a reliance on manual control. We conduct investigations into the use of a splatter gun herbicide applicator. This equipment can be carried in a backpack and relies on a higher concentration of herbicide in a low volume application.

How long will seeds remain viable when immersed in creek water and will this survival influence search buffers? Is sea water a barrier to the dispersal of viable Siam weed and limnocharis seeds?

- All weed eradication target species occur along creek lines. In a seed immersion trial in the ecology laboratory at CWTA, we compare the seed viability of *L. flava*, *C. hirta*, *M. calvescens* and two seed collections of Siam weed immersed for 2–98 days in creek water, sea water and a 50/50 mix. Results will provide baseline data for models of aquatic dispersal.

How quickly, to what levels and how regularly does *C. hirta* produce berries?

- We collect data in the field and shadehouse on the time *C. hirta* takes to flower and the size of plants at maturity. Additional observations are recorded under quarantine conditions on recovery from damage and the timing and amount of fruit and seed production.

When does *M. calvescens* mature? Does fruiting behaviour differ from overseas? How much fruit do panicles produce?

- The size of any mature plants encountered in the field is recorded and analysed, along with the growth of plants retained for research. We also monitor several backyard *M. calvescens* trees to assess timing and volume of fruit production. Pre-flowering panicles are securely bagged with fine mesh; we then record the time for formation of flowers, immature berries and mature berries. As berries mature, we remove the panicles and count the number of berries.

How persistent are *L. flava* and *M. calvescens* soil seed banks?

- Soil cores are collected regularly from an area with a high density of *M. calvescens* (prior to control) at the El Arish infestation. Seed bank studies for *L. flava* are continuing at an infestation in a constantly wet, spring-fed, lowland tropical stream near Feluga. These data will guide the duration of control and monitoring activities as there is no other information available on limnocharis seed persistence. All soil samples are sieved to remove, count and germinate seed.

Progress in 2009–10

Siam weed—age to maturity

At TWRC all of the Siam weed plants raised from Townsville seed in late October, November and December 2009 flowered in May 2010. Five out of six plants raised from seed in late January 2010 flowered in late May and were destructively harvested. In the wet tropics trial, seven out of 18 plants raised from seed between early November 2009 and mid January 2010 flowered in May 2010. Both trials show that under ideal (pot) conditions Siam weed can be raised from seed between November and January and commence flowering in May. It is not yet known how often this short timeframe for age to maturity would occur under field conditions. As plants could mature in four months, both trials highlight the importance of effectively surveying and controlling infestations between early February and flowering in May/June.

Siam weed—seed longevity

Seeds were buried in December 2009. We recorded a mean seed viability of 72% in unburied seed at the commencement of the trial. Considerable germination was noted in surface situated bags during the wet season and seed from the first retrieval (at 6 months) is currently being tested.

Siam weed—fire response

For monitoring results following the first controlled burn in October 2008, see *Technical highlights 2008–09*. Some seedlings that germinated after the first fire commenced flowering in June 2010. A general reduction in the lantana cover and good recovery of grass cover was apparent after the first fire. A second controlled burn is planned for October 2010.

Siam weed—splatter gun trials

An initial trial was conducted in March 2009. A full assessment 12 months after treatment showed that low volume applications of a fluroxypyr/aminopyralid-based herbicide resulted in high mortality. Low volume applications of glyphosate and metsulfuron-methyl herbicides were less effective, as some leaders of Siam weed continued to grow and eventually flower. The splatter gun is now used by eradication field staff where high volume herbicide applications are not feasible.

A second trial investigating the effectiveness of lower rates of fluroxypyr-based herbicides applied with a splatter gun was conducted in April 2010.

Seed immersion trials

Initial results of the seed immersion trial suggest that at least 2 weeks of immersion in any of the three water types tested is no barrier to the dispersal of viable seed for all four species included in this trial.

Clidemia—fruit and seed production

C. hirta plants were capable of producing an average of 963 fruits per plant (standard deviation = 214, n = 10) during the first 12 months following reproductive maturity. The average number of seeds produced per fruit was 801 (standard deviation = 204, n = 50), ranging between 300 and 1200 seeds per fruit. Each individual mature plant was able to produce approximately 775 000 seeds in its first year of production. Several fruiting peaks were observed on shadehouse plants throughout the year. Data collated from research plants and field crew records since 2006 indicate that *C. hirta* matures over a range of basal diameters between 5–12 mm.

Miconia calvescens—flowering behaviour

Field data collated from retained research plants and field crew records since 2004 indicate that *M. calvescens* matures over a range of basal diameters between 4–8 cm. Growth data show that the fastest growing plants can increase in basal diameter at 1.5 cm per year for a limited time, while the average is 0.5 cm per year. Most plants would therefore take at least four years to mature and up to seven or eight years in some cases; thus annual or biennial surveys should present two or more opportunities to detect plants before they mature.

M. calvescens produces flowers and fruit on panicles often 20–30 cm long. Trial data from backyard trees monitored from April 2005 to November 2009 have shown an average of 245 fruits per panicle and about 190 seeds per fruit would produce 44 500 seeds on the average panicle.

Four major annual flowering episodes commenced between January and April and took an average of 130 days (minimum 118 days) from panicle initiation to initial fruit production. A number of observations have been made of a smaller second flowering episode commencing in the spring months, demonstrating the vigilance required in reducing the opportunity for miconia to reproduce.

Miconia calvescens—seed bank persistence

We undertook annual sampling of the soil seed bank from 2004 to 2008. Future sampling will be more widely spaced to determine soil seed bank decline over time. Despite removal of adjacent mature plants in 2004, small numbers of seedlings have continued to emerge and there has been no decline in the density of seed extracted from the soil.

Table 1. Number, distribution and viability of *L. flava* seeds extracted from 40 mud samples collected between 2003 and 2009 at an infestation near Feluga, north Queensland.

Year	2003	2005	2006	2007	2008	2009
Number of seeds sieved from 40 samples	623	358	1252	489	530	323
Samples with seeds (%)	70.7	77.5	82	55.5	67.5	47.5
Average seeds per sample	15.2	9.0	31.3	12.2	13.3	8.1
Seed viability (%)	–	64.7	54.4	59.5	80.7	57.9

Limnocharis—seed bank persistence

The viability of seed extracted from the 2005–2009 (annual) samples has been tested and there has been no decrease in viability or seed density since 2003 (Table 1), although seed input has not been recorded since 2004 and the number of plants emerging at the infestation has declined over this period. Continued field emergence and the extraction of viable soil-borne seed shows limnocharis has a highly persistent seed bank.

Additional research

In early 2010, Siam weed leaf samples were collected from infestations near Mt Garnet, Mossman, Innisfail, El Arish and the Pinnacles and forwarded to Biosecurity Queensland's Natural Toxins Laboratory for analysis of chemicals potentially toxic to livestock. The outcome of this investigation may influence stakeholder awareness and support of the eradication program.

We have been testing surfactants to improve weed seed hygiene practices. An initial screening of several chemicals in the laboratory indicates Siam weed seed may be susceptible to a number of common cleaning, sterilising and depletive agents, but only at high concentrations and after greater than 10 minutes of exposure.

A small trial was established in collaboration with CSIRO Sustainable Ecosystems to measure the monthly emergence, survival and growth of *M. racemosa* plants in the field.

Funding in 2009–10

- Queensland Government
- Siam and Four Tropical Weeds Eradication Programs through national cost-share arrangements ($50 000)

Collaborators

- Biosecurity Queensland officers based at South Johnstone and Townsville provided assistance with locating and accessing trial areas.
- DERM staff conducted the controlled Siam weed burn.
- Cairns Regional Council
- CSIRO Sustainable Ecosystems, Atherton
- School of Land, Crop and Food Sciences, UQ
- Natural Toxins Laboratory, Biosecurity Queensland

More information

For further information on this research project, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

7. Class 1 weed control packages

Project dates

July 2008 – June 2013

Project leader

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Other staff in 2009–10

Barbara Madigan and Annerose Chamberlain

Objectives

Develop reliable and effective control options that can be integrated into eradication programs for Queensland Class 1 declared weeds. This includes:

- seeking a minor use herbicide permit that covers all Queensland Class 1 declared plant species
- collecting basic ecological data (e.g. time to reproductive maturity and soil seed bank dynamics) on priority Class 1 weeds
- implementing an accelerated ageing test to determine potential seed longevity on targeted Class 1 weeds (where more than 1200 mature seeds can be sourced).

Rationale

Expanding the current Queensland Class 1 plant declaration list to species level yielded a list of 8978 taxa, including hybrids, cultivars and synonyms. Restricting the list to those Class 1 species already present in Australia narrowed the total to 156, of which 44 species are currently naturalised in Queensland. For the majority of these species there is anecdotal, limited or no ecological information (e.g. age to reproductive maturity and seed bank persistence) available.

Such data are essential for enhancing the effectiveness and efficiency of eradication efforts. Furthermore, knowledge of seed bank persistence provides insights into how long programs need to be maintained and the amount of resourcing needed to achieve eradication.

Control efforts are also hindered by a lack of chemical registrations. Of the 44 naturalised Class 1 plant species, nine have chemical recommendations, 21 are captured under broader categories (for example *Acacia* spp., cacti or the Environmental Permit PER11463) and 14 have no chemicals registered. A minor use herbicide permit covering all Queensland Class 1 declared plant species would greatly aid eradication efforts and enhance Queensland's ability to respond to new incursions.

Methods

Prioritisation of Class 1 weed research

We use *Facilitator* software—a decision support system that uses decision rules and a hierarchical system for ranking criteria—to prioritise the Class 1 species list in order to achieve a manageable research program (targeting four Class 1 species annually). Criteria used for ranking species are:

- species presence in Australia or Queensland
- known effective chemical recommendations
- other known non-chemical control options
- basic knowledge of plant biology
- whether a lack of knowledge is limiting control efforts.

Ecological studies

We collect basic ecological information (e.g. flowering period, seed production, age to reproductive maturity and seed bank persistence) on prioritised species from established infestations. All seeds are collected and removed from sites. At the conclusion of the study all plants are killed.

Control studies

We develop chemical and non-chemical control options capable of being integrated into eradication programs and provide data to assist minor use applications.

Progress in 2009–10

Prioritisation of Class 1 weed research

The top four weeds identified for research in 2009–10 were badhara bush (*Gmelina elliptica*), Mexican feather grass (*Nassella tenuissima*), water mimosa (*Neptunia plena*) and Mexican bean tree (*Cecropia peltata*).

Ecological studies

A seed library of Class 1 weeds naturalised in Queensland to date contains seeds from Mexican feather grass, Mexican bean tree, trumpet tree (*Cecropia palmata*), badhara bush, *Mimosa pigra*, Koster's curse (*Clidemia hirta*) and miconia (*Miconia calvescens*).

Monitoring studies showed that the reproductive period for Mexican feather grass is from September to March, for Mexican bean tree mainly from September to June, and for badhara bush from October to June.

The field study monitoring Mexican feather grass cohorts was terminated after 11 months in January 2010. At final assessment plant height ranged from 99–600 mm, with no plants having reached maturity during the trial period. Plant mortality was 12% from early December 2009 to late January 2010. Following the removal of reproductive plants in January 2009, 90 seedlings emerged since February 2009, with 36% of plants dying (irrespective of cohort) during this period. Despite rainfall in December 2009, no new Mexican feather grass seedlings were found at the site in 2010.

A total of 58 seedlings were removed, bagged and transported to AFRS, where they were re-potted and monitored for time to reproductive maturity. Preliminary results indicate that Mexican feather grass matures in 18–24 months and Mexican bean tree in 2–3 years. Studies are ongoing.

Although flowering was prolific, water mimosa failed to produce seed at AFRS and TWRC, delaying planned seed studies. To resolve *Neptunia* identification problems in Queensland, *Neptunia oleracea* and *N. plena* DNA samples from the New York Herbarium and the Kew Royal Botanic Gardens Herbarium were sought.

Photo 1. (a) Infestation, (b) inflorescence and (c) spongy aerenchyma around stem of *N. plena*.

Accelerated seed ageing trials for Mexican feather grass, badhara bush and Mexican bean tree were completed. Mexican feather grass and Mexican bean tree seed declined to 50% viability (P_{50}) within 8.9 days and 21.9 days respectively, indicating that the seed bank of Mexican feather grass is transient (seed persistence <1 year) and Mexican bean tree's seed bank is short-lived (seed persistence 1–3 years). Despite high initial viability (>85%), badhara bush seed germinated poorly and the trial will need to be repeated.

Control studies

A chemical screening trial involving seven herbicides and three application methods (cut stump, basal bark spraying and stem injection) was initiated on badhara bush growing at the Cawarral trial site in December 2009. The cut stump method was found to be the most effective treatment for isolated infestations.

To assist Class 1 eradication efforts, minor use permits were obtained for *Nassella* spp. (PER11660), *Neptunia oleracea* and *N. plena* (PER11670), and *Chromolaena odorata* (PER11833) (for details see project report '4.2 Chemical registration' on page 86).

Funding in 2009–10

- Queensland Government
- Exotic Pest and Disease Fund, via Mexican Feather Grass and Water Mimosa Eradication Programs ($70 000)

Collaborators

- Biosecurity Queensland field staff
- Brisbane City Council
- Capricorn Pest Management Group
- Logan City Council
- Seqwater

More information

For further information on this research project, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

8. *Mimosa pigra* research

Project dates
July 2008 – June 2013

Project leader
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Other staff in 2009–10
Barbara Madigan

Objectives
- Study seedling emergence and seed bank dynamics of *Mimosa pigra* growing at Peter Faust Dam, Proserpine, to assist in the eradication of this species.
- Investigate fire and chemical options for *M. pigra* control.
- Determine the origins of *M. pigra* infestations in Queensland, Western Australia and the Northern Territory through next generation (whole genome) sequencing.

Rationale
Mimosa pigra is a WONS and a Class 1 declared weed in Queensland. Originating from Central America, *M. pigra* poses a major threat to the integrity of northern Australia×s wetlands, reducing biodiversity and affecting primary production. In the Northern Territory it has formed impenetrable, nearly mono-specific thickets over 800 km^2. In February 2001, the first infestation of *M. pigra* in Australia outside the Northern Territory was found at Peter Faust Dam, near Proserpine in central coastal Queensland. A stakeholder group was formed to eradicate the infestation. One of Biosecurity Queensland's contributions is to provide research on the biology and control of *M. pigra* to aid in the eradication effort. This includes advising on the timing of site revisits to ensure plants are detected and controlled prior to setting seed, and predicting how long the eradication effort needs to continue.

Methods
The study site at Peter Faust Dam is located on the peninsula known as Point 10, extending from the 65% water storage capacity level to the middle of the creek bed. This area includes closed canopy *M. pigra* infestations (known as core areas) and individual *M. pigra* plants scattered across the peninsula.

Seedling emergence and seed bank
We record annual seedling counts in a 5 m grid pattern across the peninsula and take soil cores annually from different areas for seed bank studies. We also test the viability of recovered seeds.

Molecular studies
Next Generation (whole genome) Sequencing of *M. pigra* DNA is undertaken by the Australian Genome Research Facility using the 454 sequencing system. Once completed, Biosecurity Queensland Molecular Biologist Dr Jane Oakey uses up to 150 microsatellite loci for *M. pigra* and determines alleles from *M. pigra* infestations in Queensland and Western Australia and from 20 reference populations in the Northern Territory.

In addition, we analyse populations from Africa (Botswana and Kenya), South and Central America (Brazil, Columbia, Costa Rica, Cuba, Ecuador, El Salvador, Guyana, Nicaragua, Venezuela and Mexico) and the Asia-Pacific region (Indonesia, Malaysia, Papua New Guinea, Thailand and Vietnam). The project aims to process up to 200 samples. This information will then be used to evaluate and compare allele frequencies between populations and determine the most likely source of each of the Australian populations.

Progress in 2009–10
Seedling emergence and seed bank
Soil cores were not extracted during 2009–10, as the core area remains inundated as a result of the heavy rains in early 2010.

Molecular studies
Next generation (whole genome) sequencing of *M. pigra* DNA by the Australian Genome Research Facility is currently in progress.

Funding in 2009–10
- Queensland Government
- Reef Catchments, via Mimosa pigra Eradication Program ($50 000)

Collaborators
- Jane Oakey, Molecular Biologist (Biosecurity Queensland)
- Kay Bailey, National WONS Coordinator for M. *pigra* and athel pine and Christopher Collins, Bert Lukitsch, Ian Cowie & Ben Stuckey (all NRETAS, Northern Teritory)
- Tim Heard and Gio Fichera (CSIRO)
- Chris Hawkins and Tracey Vinnicombe (Department of Agriculture and Food, Western Australia)

More information
Key publications
Vitelli, J.S., Madigan, B.A. and Worsley, K.J. 2006. *Mimosa pigra* in Queensland. In: *Proceedings of the 15th Australian Weeds Conference*. C. Preston, J.H. Watts and N.D. Crossman, eds. Weed Management Society of South Australia, Adelaide, South Australia. pp. 251–254.

For further information on this research project and access to key publications, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

9. Ecology and control of wet tropics weeds

Project dates

January 1999 – January 2012

Project leader

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Other staff in 2009–10

Stephen Setter and Katie Patane

Objective

Increase our understanding of the ecology and control options of key wet tropics weeds in order to improve their management.

Rationale

Weeds are a major threat to the high economic, environmental and social values of land in the wet tropics. Many wet tropics weeds are relatively recent arrivals and have not reached the full extent of their range and impact. Much of the basic ecological knowledge required to develop comprehensive long-term control strategies for wet tropics weeds is unavailable. This project conducts field, shadehouse and laboratory experiments on a number of priority weed species. Research findings will enable land managers to more effectively limit weed impacts on natural ecosystems, primary industries and tourism.

Methods

Field, shadehouse and laboratory experiments are currently underway on a number of weed species, including pond apple (*Annona glabra*), navua sedge (*Cyperus aromaticus*) and neem (*Azadirachta indica*).

Pond apple ecology

We have established multiple field and pot experiments to determine a number of ecological parameters for pond apple, including seedling mortality, age to reproduction, fruit production and seed longevity in freshwater and saltwater.

Table 1. Annual seed production (seeds ha^{-1}) of pond apple at three locations in the wet tropics.

Location	2006	2007	2008	2009	2010
Innisfail	438 400	810 800	8 282 083	6 533 000	4 681 597
Russell River	3 946 000	1 100 000	2 490 417	3 532 917	463 333
Daintree	3 069 000	3 765 000	2 432 500	1 042 500	1 368 939

Pond apple mechanical control

Mechanical control of pond apple may be a viable option in some areas during drier periods. We test two different machines—the Positrack and the Tracksaw—for their kill rate, amount of follow-up control required, cost-efficiency and selectivity (effect on native vegetation). Trials are performed in pond apple infestations of similar size and density at the Daintree (Positrack) and in Innisfail (Tracksaw). There are notable differences between the two machines: the Positrack creates mulch from the destroyed plants, while the Tracksaw has herbicide application integrated into its control method and thus requires only a single operator (for the Positrack experiment we applied herbicide by hand).

Neem spread

Since 2002, we have monitored a site on the Gilbert River in north Queensland on an annual basis to estimate the rate at which this potential weed can colonise riparian areas. The percentage of cover is estimated in six 20 metre-long transects.

Navua sedge

In 2002, we commenced a seed longevity trial, with seed lots buried at three depths (0 cm, 2 cm and 10 cm) in the soil profile. We then retrieve seeds for germinability and viability testing after 1, 2, 3, 4, 5, 10 and 15 years.

Progress in 2009–10

Pond apple ecology—seedling mortality and age to reproduction

Of 520 seedlings tagged in the field, less than 8% survived for three years. The shortest time to reproduction was 3.5 years (this plant was 2.5 m high, with a 70 mm basal diameter). Plants growing under shadehouse conditions haven't flowered after 2 years. Monitoring is ongoing.

Pond apple ecology—fruit production

The field fruit-trapping component of this research has been finalised after five years of data collection, and data will now be analysed. Preliminary results show great fluctuations between sites and years in annual seed production, ranging from approximately 440 000 to over 8 million seeds ha^{-1} (Table 1).

Pond apple ecology—seed longevity in water

Seeds placed in saltwater retained 49% germinability after three years but germinability was reduced to 1.3% after four years. Seeds placed in freshwater remained germinable for up to two years and eight months. After three years they had all either germinated in the water or expired.

Pond apple mechanical control

We have established transects and applied the mechanical control treatments; monitoring and analysis is ongoing. Preliminary results show that 6 months after treatment, mortality of pond apple was 90% for the Tracksaw experiment; the experiment using the Positrack with or without additional herbicide application by hand killed 85% and 99% of pond apple plants respectively.

Neem spread

The average initial canopy cover of neem (23% in 2002) had increased to 88% after five years and decreased since then to approximately 71% in 2009. The reason for the decrease in the last two years is unclear. While we did not directly measure the native woody vegetation, anecdotal evidence suggests that *Melaleuca* spp. have also declined notably in this area.

Photo 1. The Positrack is a tracked bobcat with a robust slasher-type attachment that cuts individual trees off near ground level and reduces them to mulch.

Photo 2. The Tracksaw is a tracked mini-excavator with a chainsaw bar and spray applicator on the boom that cuts individual trees off near ground level and applies chemical immediately to the cut stump.

Navua sedge

The year five sampling associated with the seed burial trial was undertaken in July 2007 and showed less than 1% viability for surface-situated seeds, and 27.5% and 17% viability for seeds buried at 2 and 10 cm, respectively. The next samples are due to be retrieved and tested in 2012.

Funding in 2009–10

- Land Protection Fund ($44 000)
- Queensland Government

Collaborators

- Cairns Regional Council
- Cassowary Coast Regional Council
- Far North Queensland Regional Organisation of Councils

More information

Key publications

Westcott, D.A., Setter, M., Bradford, M.G., McKeown, A. and Setter, S. 2008. Cassowary dispersal of the invasive pond apple in a tropical rainforest: The contribution of subordinate dispersal modes in invasion. *Diversity and Distributions* 14(2): 432–439.

Mason, L.B., Setter, M.J., Setter, S.D., Hardy, T. and Graham, M.F. 2008. Ocean dispersal modelling for propagules of pond apple (*Annona glabra* L.). In: *Proceedings of the 16th Australian Weeds Conference*. R.D. van Klinken, V.A. Osten, F.D. Panetta and J.C. Scanlan, eds. Queensland Weeds Society, Brisbane, Queensland. pp. 519–521.

Setter, S.D., Setter, M.J., Graham, M.F. and Vitelli, J.S. 2008. Buoyancy and germination of pond apple (*Annona glabra* L.) propagules in fresh and salt water. In: *Proceedings of the 16th Australian Weeds Conference*. R.D. van Klinken, V.A. Osten, F.D. Panetta and J.C. Scanlan, eds. Queensland Weeds Society, Brisbane, Queensland. pp. 140–142.

For further information on this research project and access to key publications, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

10. Population viability analysis models for better management of lantana (*Lantana camara*)

Project dates

July 2008 – June 2012

Project leader

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Other staff in 2009–10

Christine Perrett and Cameron Clark

Objectives

- Use size-structure population matrices and mathematical models to examine vital rates of growth, reproduction and survival of *Lantana camara* under various landscape scenarios in order to project its population growth into the future.
- Identify, from a suite of demographic parameters and with the aid of computer simulations and model predictions, the main driver/s of population growth that could be manipulated for management purposes.

Rationale

Lantana (*Lantana camara*) is a WONS and a Class 3 declared plant in Queensland. Despite millions of dollars spent on control, research and extension work, there is a dearth of quantitative data encompassing the entire life cycle of the weed. To date, no attempt has been made to carry out population viability analysis studies on the species, despite the widely held view that population viability analysis, when done in concert with sensitivity analysis and numerical simulations, could help greatly in fine-tuning management strategies for control of invasive organisms. This project aims to fill this apparent gap in our understanding of the invasion biology of lantana.

Methods

We set up and census permanent plots of 50 m × 50 m at each of four sites in the Yarraman/Blackbutt area west of Brisbane (Figure 1) to parameterise lantana's vital rates (seed germination and dormancy, seedling, juvenile and adult growth and survival, and adult fecundity) for projection of its population growth. The four field sites (hoop pine plantation, natural forests subject to either periodic burning or grazing regimes and cattle property) contain, in increasing order, low to moderate infestations of lantana, but differ in soil properties, rainfall intensity, land use type and weed control practices.

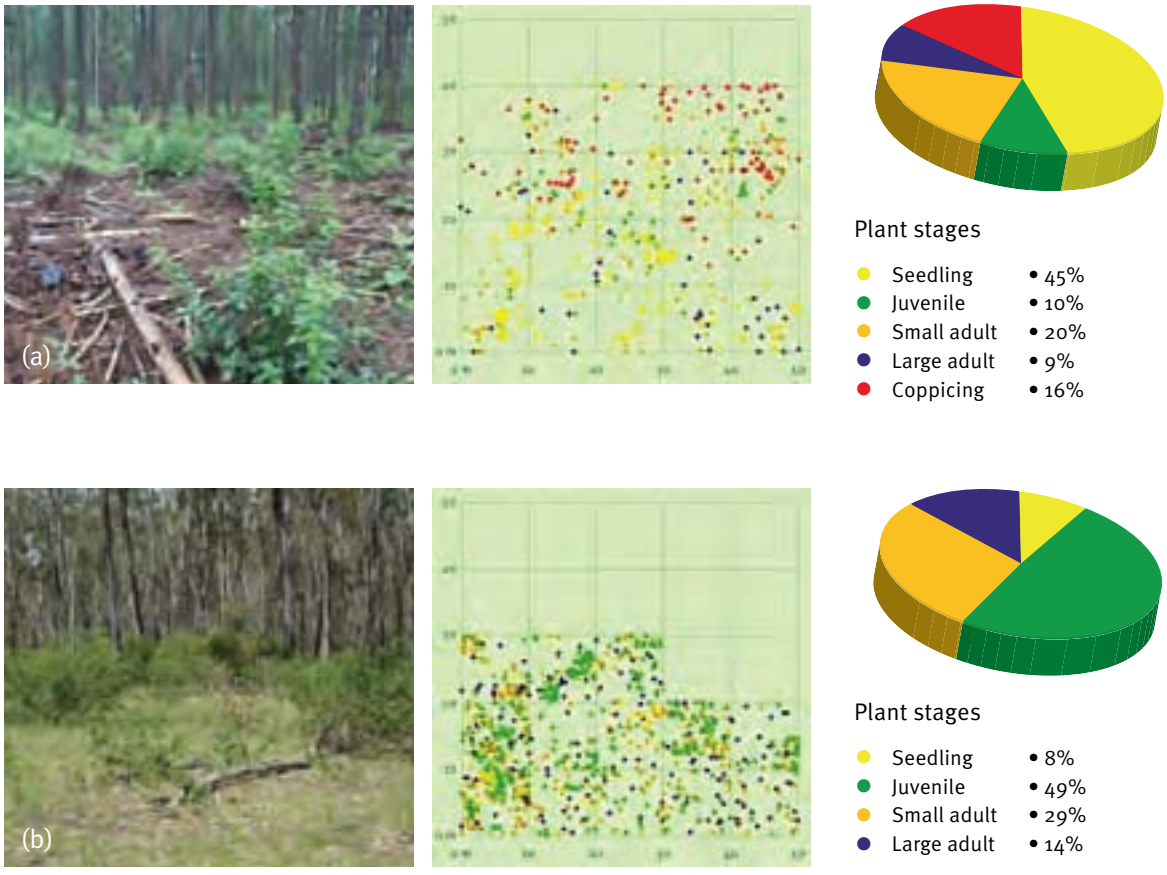

Figure 1. Lantana plants in the Yarraman/Blackbutt area (a) in a hoop pine plantation following a pine thinning operation, and (b) in a natural (eucalyptus) forest with a periodic grazing regime. Position of individual plants in a permanent plot within each of the sites is also shown.

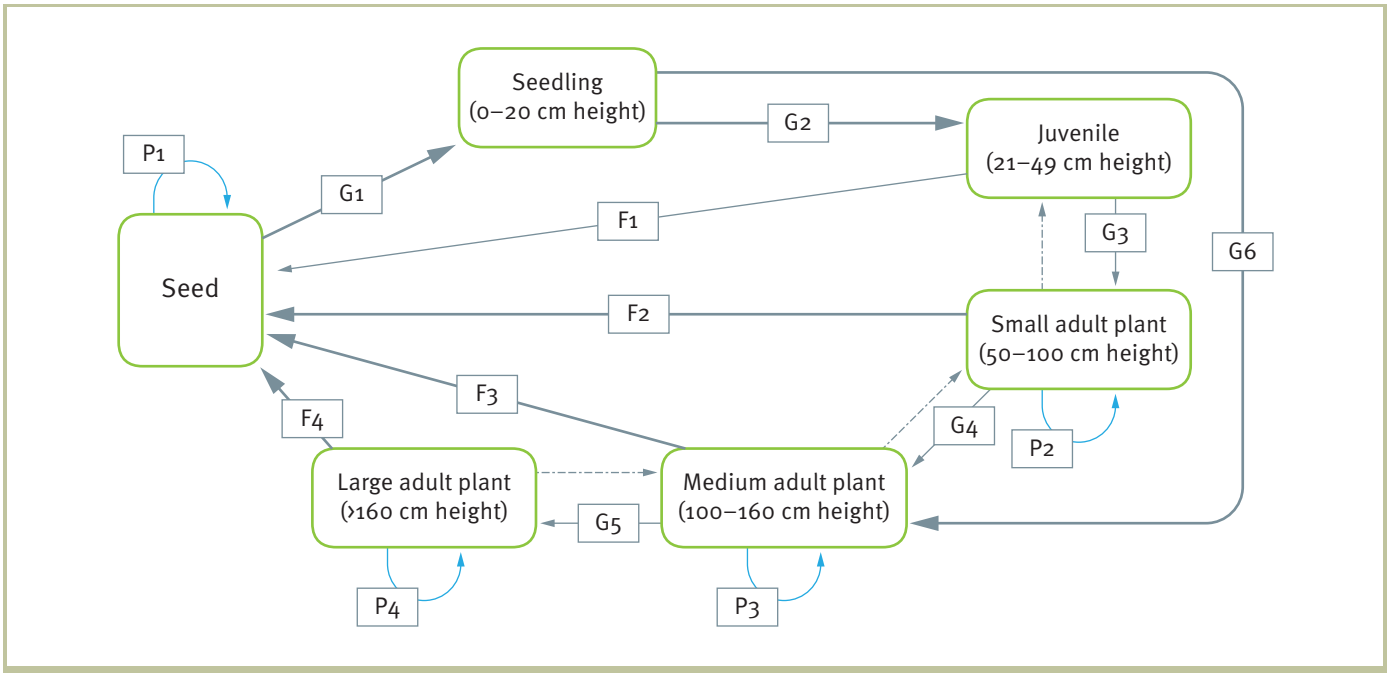

Figure 2. A stage based life cycle of lantana used in development of growth parameters for the weed. G_n = transition value for growth; P_n = survival value and F_n = fecundity/reproduction value. Back transition (i.e. reduction in plant size) is possible for reproductive adults (faint lines), especially under management regimes such as use of a biological control agent or herbicide. Thick arrows indicate transitional values contributing more than 10% to the population growth rate (λ) in the expansion phase of a weed invasion (i.e. in the hoop pine plantation).

Progress in 2009–10

The second survey and census to document population dynamics across the four field sites—consisting of more than 2000 permanently tagged lantana plants—were completed. The 2008 and 2009 survey data have now been used to develop growth dynamics, including population growth rates (λ) for the weed.

The stochastic models run for each site and projected for 10 years predicted population increases for lantana in three of the sites (hoop pine plantation: λ = 7.80; eucalyptus forest subject to periodic fire: λ = 2.672 and cattle property: λ= 2.328) and stability in one (eucalyptus forest subject to periodic grazing: λ = 0.996). The projected population growth rate in the hoop pine plantation was highest, which is typical of the early phase of invasion this site is currently experiencing following a clearing event in January 2008.

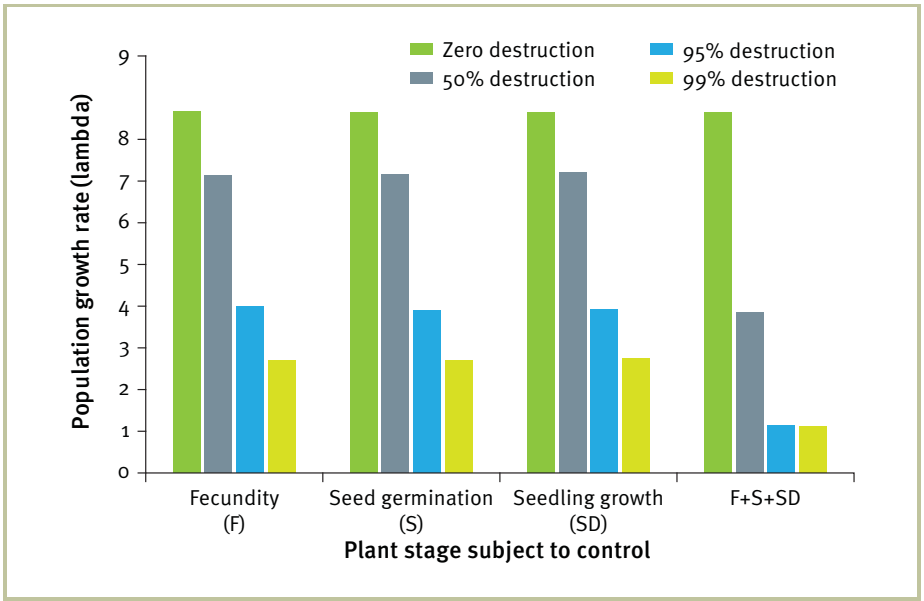

Figure 3. Summary of numerical analyses examining the effect of management intervention on a lantana population in its expansion phase (i.e. using lantana demographic data from the hoop pine plantation). Simulations involved destruction of either zero, 50%, 95% or 99% of each of the three plant stages earlier identified as the main drivers of population growth rate.

Certain transitions are clearly overwhelmingly important in the life cycle of lantana (Figure 2). In the expansion phase (i.e. at the hoop pine plantation), traits of the weed that contributed most to its population explosion were transition values representing seed germination (29.1%), seedling growth to medium size plants (18.9%) and seed production (fecundity) for both medium and large size plants (12.8% and 14% respectively, Figure 2). These four transition values make up 75% of the contribution to λ. Similar patterns occurred in the mid-phase of invasion, as exemplified by lantana growth dynamics in the eucalyptus forest subject to periodic fire and on the cattle property. For these sites, seed germination (19% to 23%), seedling growth to juvenile/medium size

plant (17% to 23.2%) and seed production (10.9% to 14%) contributed most to λ. For the lantana infestation whose population growth is close to unity (i.e. the eucalyptus forest under a periodic grazing regime), adult plant survival contributed most to λ (41%, 24% and 12% for small, medium and large plants respectively). Overall (i.e. across sites), plant growth contributed more (62%) to population growth than did survival (14%) and fecundity (24%).

We used growth dynamics in the hoop pine plantation to model the potential capability of biological control agents (e.g. insects such as *Aconophora compressa* or *Ophiomyia lantanae*) in halting an expanding population of the weed. We assumed gradual population build-up of the bioagent, and hence an increase in its efficacy as follows: 50%, 95% and 99% destruction of a given life history stage of the weed. The simulation results are presented in Figure 3. None of the hypothetical simulations of biological control agent effect succeeded, on its own, in achieving negative population growth of the weed (i.e. $\lambda < 1.0$). Similarly, singularly controlling one of the plant stages whose contributions were deemed important to growth rate (i.e. seed germination, seedling growth and fecundity) did not result in λ falling below one. However, it does appear that joint action involving at least 95% reduction in fecundity, seed germination and seedling growth can succeed in stabilizing weed population growth (i.e. $\lambda = \sim 1.0$).

Environmental variability is the norm rather than the exception. In order to build a robust projection model with a good degree of accuracy, we will continue to monitor the fates of all mapped and tagged individuals and new recruits of lantana plants in each of the four sites for another one to two years. Such long-term demographic information, when combined with economic data, will assist in making informed decisions on the feasibility of local control/eradication of the weed.

Funding in 2009–10

- Queensland Government
- Land Protection Fund ($42 000)

Collaborators

- Yvonne Buckley (Spatial Ecology Lab, UQ)
- S. Raghu (CSIRO Sustainable Ecosystems, Brisbane)

More information

For further information on this research project, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

11. Impacts of environmental weeds on soil processes

Project dates
January 2010 – December 2012

Project leader
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Other staff in 2009–10
Christine Perrett and Cameron Clark

Objective
Document the impacts of environmental weeds on soil processes.

Rationale
The presence of exotic plants with aggressive demographic traits (high fecundity, high survival, high structural dominance) poses a serious threat to natural ecosystems. Lantana (*Lantana camara*) and various weedy vines—e.g. cat's claw creeper (*Macfadyena unguis-cati*) and Madeira vine (*Anredera cordifolia*)—are exotic weeds of great significance in Queensland and at the national level. Currently, there is little quantitative information on changes in below-ground (soil) ecosystem properties mediated by the presence of these invasive species, including changes in physicochemical properties, insect diversity and microbial activity.

Methods
At four field sites of varying land use type in the Yarraman/Blackbutt area west of Brisbane (see project report '2.10 Population viability analysis models for better management of lantana' on page 51), we collect soil samples beneath and away from established lantana patches (n=4 samples per site) to document the likely effect of the weed on

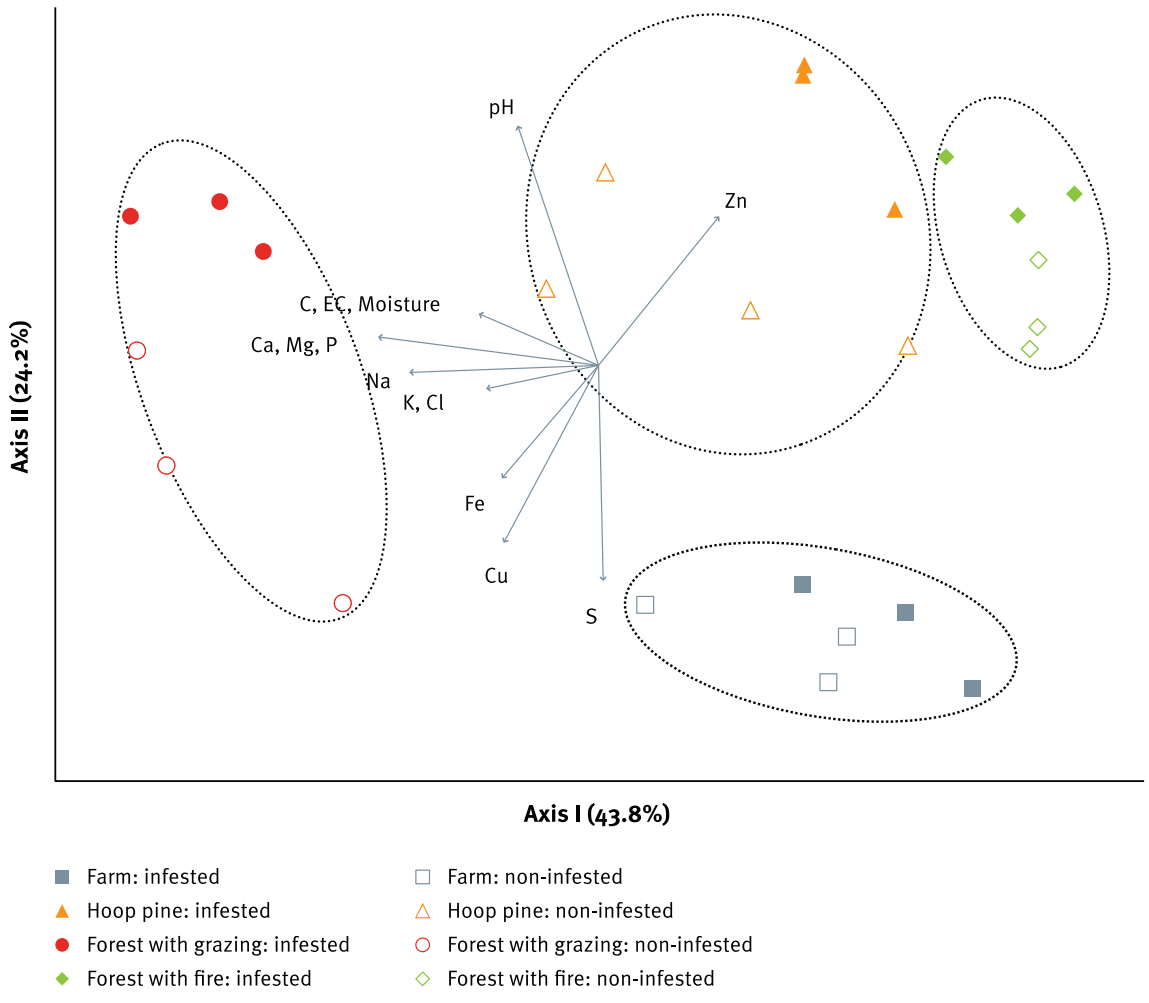

Figure 1. Ordination of soils underneath (closed symbols) and away from (open symbols) lantana patches across four field sites of varying land use type. Arrows indicate direction and magnitude of soil traits driving each axis. Faint loops indicate field sites. (C = Carbon; Ca = Calcium; Cl = Chloride ion; Cu = Copper; EC = Electrical conductivity; Fe = Iron; K = Potassium; Mg = Magnesium; Na = Sodium; P = Phosphorus; S = Sulphur and Zn = Zinc.)

23 soil physicochemical properties. The data collected are then subjected to a multivariate ordination technique (see Figure 1).

Progress in 2009–10

A significant site effect was more frequently observed than an effect due to invasion status. Consequently, major axis I (capturing 43.8% of data variation) did not show a clear dominance of any particular (or group of) soil traits, nor did it separate the invasion status of the soils surveyed (Figure 1). Rather, it served as a location (site) axis, separating the soil physicochemical properties in the eucalyptus forest with grazing regime from the other sites. Major axis II (capturing 24.2% of data variation) provided some clear separation of soil within lantana infestations from soil lacking the weed, especially when viewed from the individual site perspective. ANOVA results of the vector loadings (scores) of the data points on this axis indicated that at each site, the soils in lantana-infested and non-infested patches differed significantly ($p < 0.05$), except for the farm site (Figure 1). Soil traits having major influence on this axis (in decreasing order) were pH, sulphur, zinc, iron, organic carbon and copper. Axis III captured 14.5% of data variation and was driven largely by nitrate and manganese, but did not contribute to separation of the sites, nor to differences, in the soils based on invasion status.

In summary, about half of the 23 soil traits examined differed significantly between infested and non-infested soils. Moisture, pH, calcium, total and organic carbon, and total nitrogen (but not exchangeable nitrogen in form of nitrate) were significantly elevated, while sodium, chloride, copper, iron, sulphur and manganese, many of which can be toxic to plant growth if present in excess levels, were present at lower levels in soils supporting lantana compared to soils lacking the weed. These results indicate that lantana can improve soil fertility and influence nutrient cycling—making the substratum ideal for its own growth. This may explain the ability of the weed to outcompete other species, especially native ones.

We are now investigating other invasive species such as cat's claw creeper in relation to their effects on soil ecosystems.

In addition:

- We have collected leaf samples of the weeds, together with those of one or two co-occurring native plant species, for chemical analyses to explore further the mechanism/s underlying the below-ground changes in some of the mineral ions in infested patches.
- We have established permanent soil depot points within and outside weed patches for long-term monitoring of soil processes, especially moisture, insect diversity and microbial activity including soil respiration (Photo 1).

Funding in 2009–10

Queensland Government

Collaborators

- DERM Landscape Sciences
- Dr Alan Andersen (CSIRO Sustainable Ecosystems, Darwin)

More information

Key publications

Osunkoya, O.O., Pyle, K., Scharaschkin, T. and Dhileepan, K. 2009. What lies beneath? The pattern and abundance of the subterranean tuber bank of the invasive liana cat's claw creeper, *Macfadyena unguis-cati* (Bignoniaceae). *Australian Journal of Botany* 57(2): 132–138.

For further information on this research project and access to key publications, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

Photo 1. Experimentalist Christine Perrett undertaking soil respiration measurements in a cat's claw creeper–infested landscape.

12. Water weed management and control

Project dates

June 2009 – August 2010

Project leader

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Other staff in 2009–10

Cameron Clarke and Christine Perrett

Objectives

- Investigate the ecological impacts of both native and exotic floating aquatic macrophyte species.
- Research the seasonal efficacy and ecological impacts of currently registered and new unregistered herbicides to control exotic floating aquatic macrophytes.

Rationale

Floating aquatic macrophytes include some of the world's worst invasive plant species: water hyacinth (*Eichhornia crassipes*), salvinia (*Salvinia molesta*) and water lettuce (*Pistia stratiotes*). However, the less conspicuous native floating macrophytes azolla (*Azolla* sp.) and duckweed (*Lemna* sp. and *Spirodela* sp.) can also be problematic and have to be managed if growing excessively.

Floating macrophytes are thought to profoundly impact on aquatic ecosystems when growing excessively by preventing light penetration necessary for photosynthesis by submerged primary producers and interfering with the oxygenation of freshwater ecosystems.

Apart from significant ecological impacts, floating macrophytes interfere with human water usage (recreation, health issues, water loss through evapotranspiration, irrigation, damage to infrastructure). To cope with the problems created by floating macrophytes, regular management is necessary, which is economically costly and an ongoing commitment as plants rarely get completely removed from a site.

Herbicides are routinely used to control floating macrophytes and can be very efficient in controlling infestations, but can also have negative impacts on water quality. Large masses of decaying macrophytes can lead to deoxygenation of water bodies and can be detrimental to the health of aquatic ecosystems. Furthermore, the sudden release of large amounts of nutrients from the decomposing plant mass can trigger algal blooms which could negate benefits of macrophyte control.

To lessen the economic and environmental impacts of aquatic weeds, we need to improve our understanding of their ecology and environmental impacts. Output from this project will give valuable information for future weed management strategies by increasing efficacy of control measures and careful consideration of possible impacts of different management scenarios.

Methods

We conduct two separate experiments:

Experiment 1 investigates the impacts of native and exotic floating aquatic macrophytes on water quality (oxygen, pH, temperature), water quantity (evapotranspiration) and light availability below the plant canopy in small ponds at AFRS. Ponds were either stocked with floating aquatic macrophytes of each species (four replicates) or served as controls (water only) (Photo 1). We measure water physicochemical parameters and plant stand characteristics on a monthly basis. Additionally, biomass of the plants is monitored to relate biomass to ecological impacts.

Experiment 2 was conducted in separate smaller tanks, where we treat three species of exotic floating aquatic macrophytes with nine registered and unregistered herbicides on a seasonal basis. After spraying with herbicides, we assess efficacy of the treatments. This includes weekly monitoring of damage to plants and the impact of the treatment on water quality (nutrient release due to decay).

Progress in 2009–10

Ecological impacts of floating aquatic macrophytes

Plant growth

There was a wide range in average biomass production for the different macrophyte species. While the two native species (azolla

Photo 1. Plastic ponds used for the floating macrophyte ecology experiment. Water hyacinth is shown in the foreground, duckweed to the left and a control (open water) pond to the right.

Table 1. Areal cover (% plant cover of tank area), biomass (g wet weight m^{-2}) and canopy height (mm plant height above water surface) for the different macrophyte species averaged over all seasons.

	Exotic species			Native species	
	Water hyacinth	Water lettuce	Salvinia	Azolla	Duckweed
Areal cover (%) ± SD	89 ± 8	73 ± 34	85 ± 19	93 ± 11	92 ± 14
Biomass wet (g m^{-2}) ± SD	19 471 ± 6302	8785 ± 6296	3973 ± 1776	892 ± 486	2288 ± 1572
Canopy height (mm)	75–550	3–150	1–55	1–5	<1

and duckweed) averaged only about 1–2 kg wet weight m^{-2}, the exotic plants accumulated much higher biomasses (Table 1). This was especially prominent for water hyacinth, which averaged more than 19 kg wet weight m^{-2} (up to 25 kg wet weight m^{-2}).

Beside biomass, the growth form of native and exotic macrophytes also differed considerably. While duckweed and azolla merely cover the surface and hardly form a canopy more than a few millimetres thick, the exotic species grow much taller and structurally more complex, with water hyacinth growing up to 0.55 m in the experimental tanks. The difference in biomass and structure of exotic and native macrophytes affects the way light penetrates the canopy and the loss of water through evapotranspiration.

Evapotranspiration

There was a pronounced difference in evapotranspiration between the different plant species. The native azolla and duckweed and the exotic salvinia had only a negligible effect on water loss (Figure 1). However, water loss was considerably higher in tanks planted with water hyacinth or water lettuce. Interestingly, water loss appears to be more closely related to plant biomass than climatic conditions, as highest transpirative losses were encountered at time of maximum biomass towards the end of the experiment. At this time (autumn–winter) temperatures and solar exposure were low.

Light availability

All floating macrophyte species had a significant shading effect and there was always only a fraction of the light (<20%) available just below the canopy (Figure 2). Water hyacinth and salvinia had the highest impacts, nearly completely filtering out all light. With the fast growth of water lettuce in the last few months, a strong shading effect can also be seen in this species. Nevertheless, the native azolla and duckweed also showed strong temporary shading effects.

Efficacy and impacts of herbicide control

Response to the different herbicides varied widely between plant species. With contact herbicides (diquat and Immerse®—containing 50 mL L^{-1} calcium docecyl-benzene sulphonate as the active ingredient), plant damage could be seen soon after application; the plants were killed within days and would sink and start to decompose soon after. Systemic herbicides (amitrole, glyphosate, imazapyr, metsulfuron and 2,4-D), on the other hand, worked much less rapidly. Salvinia was the hardest to control, with a lower degree of herbicide damage and a lower reduction in biomass compared to water hyacinth and water lettuce. Results for water hyacinth are described in more detail below.

For water hyacinth, all of the products killed, or at least badly damaged, the majority of plants by the end of the experiment (Figure 3). Immerse®, amitrole and glyphosate were less effective than other products. There was some seasonal variability, with lower plant damage in the cooler months. Brine (saturated NaCl solution) was very efficient in controlling water hyacinth in spring, but did not kill plants in other seasons.

Oxygen availability was generally low in most of the water hyacinth tanks and fluctuated widely over time in some of the treatments. Hypoxia was consistently detected in tanks shortly after treatment with imazapyr, metsulfuron, diquat, 2,4-D and glyphosate. Therefore, all effective herbicides can lead to hypoxia.

Conclusions

Both native (azolla, duckweed) and exotic (water hyacinth, water lettuce, salvinia) floating macrophytes altered the

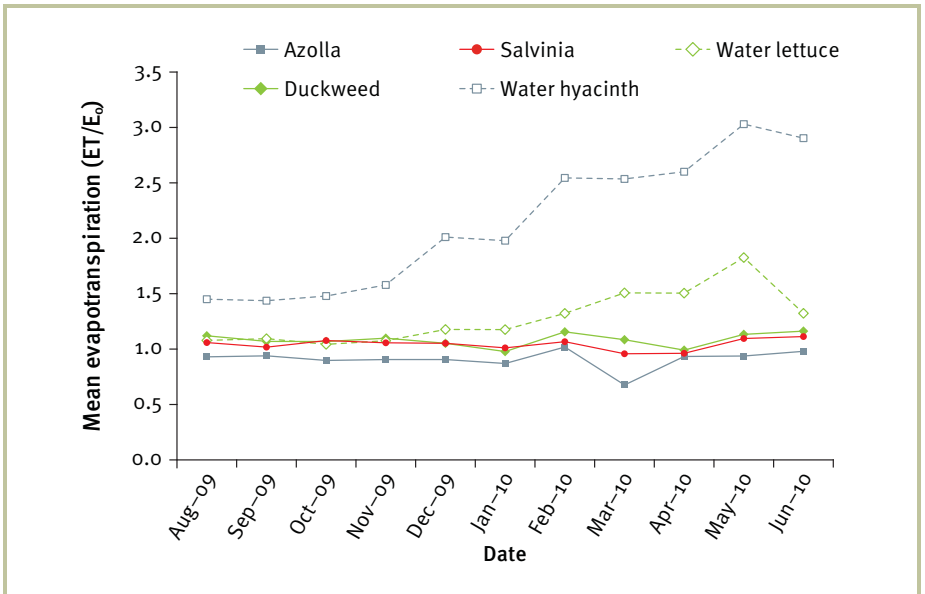

Figure 1. Mean evapotranspiration (ET) of exotic and native floating macrophytes in relation to evaporative loss of an open water surface (E_o).

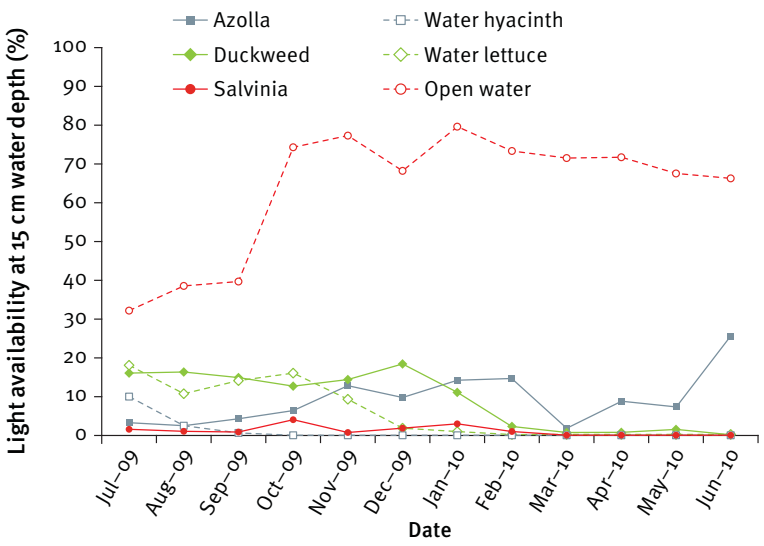

Figure 2. Light availability (% of surface light) below the floating macrophyte canopy. Algal photosynthesis entirely ceases below 1%. Note the lower light availability in open water for the first three months due to initial algal growth and resulting turbidity of the water; once the systems stabilised water clarity improved, which increased light availability in this treatment.

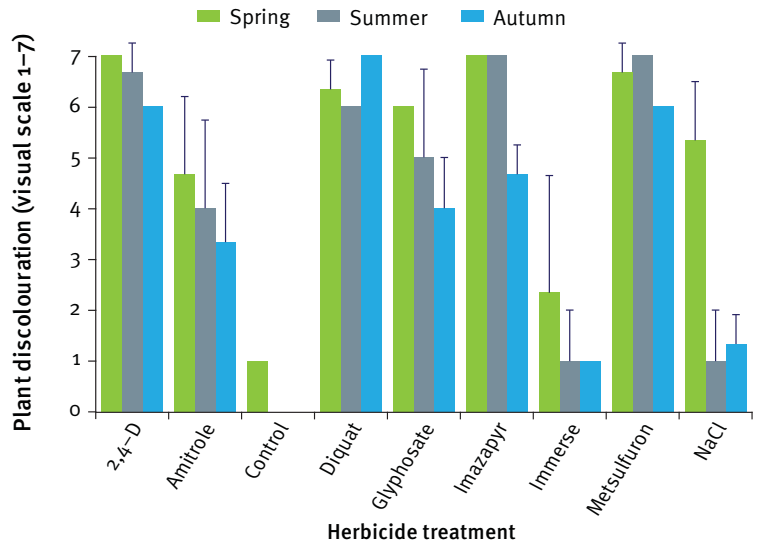

Figure 3. Herbicide damage to water hyacinth as assessed by visual inspection. Plants were scored for discolouration on a scale from 1 (healthy plants, no damage) to 7 (all plants killed).

mesocosm environment to a degree that can be considered ecologically problematic. Foremost, the dense floating canopies of all species blocked light, which could have serious implications for the functioning of freshwater ecosystems. But only water hyacinth and water lettuce considerably increased water loss through transpiration. Water hyacinth also most frequently caused hypoxic conditions and acidification of the mesocosm water. Therefore, control of water hyacinth should be a priority from a management perspective due to the severity of its impacts.

The three exotic floating macrophytes responded variably to the nine tested herbicides. If a fast destruction of plant infestations is required (public visibility), diquat would be the herbicide of choice to control water hyacinth and water lettuce; however this will temporarily increase nutrient concentrations, which could add to problems with algal blooms. The use of metsulfuron or imazapyr should be preferred if permitted, as plants die back less rapidly, which puts less stress on aquatic ecosystems. Overall, water hyacinth was best controlled by 2,4-D, water lettuce responded well to most herbicides and salvinia was most effectively controlled by glyphosate.

Funding in 2009–10

Land Protection Fund ($134 000)

Collaborators

- Brisbane City Council
- CSIRO
- Seqwater

More information

Key publications

Bickel, T.O. 2010. *Quantifying aquatic weed impacts and reducing herbicide use through seasonal efficacy trials*. Final Report to the Department of Agriculture, Fisheries and Forestry, Canberra.

For further information on this research project and access to key publications, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

Part 3 Pest animal management

1. Livestock guardian dog/wild dog (*Canis lupus familiaris* and *C. l. dingo*) interaction study

Project dates
May 2009 – December 2011

Project leader
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Other staff in 2009–10
Damian Byrne

Objectives
- Investigate the spatial and temporal movements of guardian dogs in relation to sheep and adjacent wild dogs, in particular the degree to which guardian dogs and wild dogs intermix.
- Evaluate mesopredator and native wildlife responses to the presence of livestock guardian dogs.
- Assess whether there is any interbreeding between guardian dogs and wild dogs.
- Develop and disseminate recommendations for best practice guardian dog management.

Rationale
Wild dogs (*Canis lupus familiaris* and *C. l. dingo*)—dingoes and dingo–domestic dog hybrids—are believed to deliver biodiversity benefits by suppressing mesopredators (foxes and feral cats) and preying on overabundant large macropod species. However, at the same time sheep and goat production is at risk because past satellite tracking of wild dogs shows that 25% of male wild dogs disperse over 100 km and up to 500 km from their natal area. The frequency and magnitude of these movements make it unrealistic to establish buffers that are sufficiently wide to protect sheep and goat producers from livestock predation.

Livestock guardian dogs can be considered a 'placebo wild dog' in a sheep production environment. The initial study site, Dunluce Station, near Hughenden, runs 20 000 sheep with minimal annual predation loss, yet is surrounded by beef cattle properties with known wild dog populations and predation losses. Prior to using guardian dogs in 2001, land managers regularly baited with 1080 (sodium fluoroacetate) and shot wild dogs, yet suffered 15% annual loss of sheep to wild dog attacks.

Given such apparent benefits, guardian animals could prove to be a future management imperative for protecting sheep and goats from the ingress of dispersing wild dogs. Although guardian dogs are increasingly used by graziers, there is currently very little known about how guardian dogs 'work' in Australia—particularly in extensive grazing systems—and even less about their night-time movements and interaction with wild dogs. Anecdotal accounts suggest some guardian dogs are effective at preventing wild dogs from attacking livestock, while others have been seen associating with wild dog packs. One critical management concern is the potential for guardian dogs to interbreed with wild dogs, producing larger, more aggressive and destructive hybrids. While neutering guardian dogs is the recommended practice, many are not (or only the females are) neutered.

Methods
Spatial and temporal movements
We place GPS collars on maremma guardian dogs on Dunluce Station to record half-hourly locations for over 12 months (downloaded quarterly), monitoring their daily movement patterns and annual seasonal changes in activity. We are particularly interested in activity pattern differences between individual guardian dogs in relation to their gender and social status (as seen in wild dogs and reported by guardian dog owners) and how sheep paddocks and adjacent paddocks are patrolled. Concurrently, we capture wild dogs in adjoining paddocks (<5 km from sheep) and fit them with GPS/Argos transmitters recording hourly locations.

We overlay GPS location data for wild dogs and maremmas on satellite imagery of the properties using Geographic Information Systems to identify any overlap of movements and territory boundaries. If

Photo 1. Ann Stewart-Moore of Dunluce Station releasing 'Ringo', one of their maremma guardian dogs fitted with a GPS tracking collar.

overlap exists, we investigate the temporal relationships between guardian dogs and wild dogs.

Interbreeding

DNA is collected from tissue samples or blood at the time of collaring and from dogs shot or trapped locally. At Dunluce, all working dogs are desexed, but the data will provide an important comparison for the second year of this study.

Biodiversity impacts

Simultaneously, we monitor the activity (a measure of relative abundance) of wild dogs, guardian dogs (much greater foot length), macropods, foxes and feral cats within and outside the protected paddocks from spoor at tracking stations, using the Activity Index methodology (Allen *et al*. 1996). Tracking stations, 1 km apart, are monitored for three consecutive days.

Progress in 2009–10

We have monitored the half-hourly locations of eight maremmas continuously since May 2009. While most guardian dogs remain closely associated with the sheep, others show forays well beyond their assigned paddocks.

In April 2010, we also captured and collared four wild dogs with satellite transmitters. From the limited data received to date, some of these wild dogs frequent adjoining paddocks containing sheep, yet no predation occurred.

In April 2010, we also surveyed wildlife activity on Dunluce, discovering few foxes, cats and wild dogs on the property.

Funding in 2009–10

- Queensland Government
- Australian Pest Animal Management Program, DAFF ($30 000)

Collaborators

Ninian Stewart-Moore (Dunluce owner/ Leading Sheep North and Central West regional committee)

More information

References

Allen, L., Engeman, R. and Krupa, H. 1996. Evaluation of three relative abundance indices for assessing dingo populations. *Wildlife Research* 23(2): 197–206.

For further information on this research project and access to key publications, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

Photo 2. On prepared tracking stations the spoor of various wildlife are identified and recorded each day to produce a relative abundance estimate based on activity.

2. PAPP—a new toxin for managing wild dogs (*Canis lupus familiaris* and *C. l. dingo*), foxes (*Vulpes vulpes*) and feral cats (*Felis catus*)

Project dates
July 2009 – July 2010

Project leader
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Other staff in 2009–10
Damian Byrne

Objective
Field-test a prototype PAPP wild dog bait to demonstrate its effectiveness for APVMA registration purposes.

Rationale
The toxic compound 1080 (sodium fluoroacetate) has been the primary means of mitigating the damage caused by wild dogs (*Canis lupus familiaris* and *C. l. dingo*) and foxes (*Vulpes vulpes*) to livestock since the 1960s. However, 1080 has no antidote, a relatively long time to death with protracted symptoms (and so appears inhumane), and can lead to secondary poisoning in domestic dogs and other non-target animals. As a supplement to 1080, the toxin PAPP, which has none of these problems, has been the focus of research by the Invasive Animal CRC for many years. With Biosecurity Queensland's Inglewood facilities (Robert Wicks Pest Animal Research Station) and research staff playing a crucial role, PAPP research had progressed to a point where a PAPP/bait substrate had been successfully field-tested on foxes, but needed to be field-tested on wild dogs.

Methods
In July 2009, a field trial commenced south-west of Toowoomba. In a 400 km^2 fenced area of Kumbarilla State Forest, we capture wild dogs and collar them with VHF radio transmitters. In an adjoining, similar sized but unfenced area of forest, we capture and collar wild dogs with satellite transmitters.

We then lay PAPP-poisoned and non-toxic baits in these two areas and monitor bait stations, 500 m apart, daily for 10 days. We also use remote cameras and pre- and post-baiting surveys of wildlife activity to monitor the fate of the baits and measure the effectiveness of the new toxin.

Effectiveness is measured by:

- the number of wild dogs destroyed in the baiting program (confirmed by the presence of coloured beads in the bait)
- the number of PAPP baits removed from stations
- images of dogs pre- and post-baiting, and
- changes in the Activity Index.

Progress in 2009–10
We captured and collared a total of 13 wild dogs with VHF radio transmitters and 12 wild dogs with satellite transmitters. The field trial was compromised by excessive rain in December and January, which erased the spoor of animals at bait stations, rendered the area inaccessible and washed away the fences that contained the radio-collared wild dogs in the baited area. To date, we have not been able to relocate some animals to determine their fate.

The trial was successful, but detailed results are commercial-in-confidence. The results demonstrated the effectiveness of PAPP but, viewed in isolation, they are not sufficiently conclusive, necessitating a further PAPP field trial in 2010.

Funding in 2009–10
Invasive Animal CRC ($23 000)

Collaborators
- Invasive Animals CRC
- Australian Wool Innovation Ltd
- Animal Control Technologies Australia
- Connovation Ltd
- Pestat Pty Ltd
- University of Western Sydney
- Industry & Investment New South Wales
- Department of Primary Industries, Victoria
- Department of Sustainability and Environment, Victoria

More information
For further information on this research project, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

3. Evaluating monitoring techniques for feral cats (*Felis catus*) and foxes (*Vulpes vulpes*) in south-eastern Queensland

Project dates

January 2007 – December 2009 (completed)

Project leader

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Other staff in 2009–10

Matt Gentle

Objectives

- Assess current techniques for monitoring population densities of cats and foxes.
- Investigate the effectiveness of ground shooting as a control technique.

Rationale

The ability to census and monitor a pest animal species is vital for its successful management. Without reliable information on abundance and distribution, it is difficult to evaluate the magnitude of the problem, the impacts of the pest species and the effectiveness of control programs.

Recently, there has been a push to standardise monitoring techniques for feral cats (*Felis catus*) in Australia (see DEWHA's *Threat abatement plan for predation by feral cats*). The density of the species and the characteristics of the habitat being monitored can greatly influence the logistics of different monitoring techniques as well as the reliability of results. Additionally, there have been no broadscale assessments of the effectiveness and efficiency of ground shooting of predators as a control technique.

Methods

The study area is located in the southern Brigalow belt.

Movement studies

Feral cats and foxes are trapped, fitted with GPS collars and conventional VHF radio collars (with just mortality sensors) and released. The GPS collars have a logging rate of one point every five minutes for a 24-hour period then off for six days before repeating the cycle. Such a high logging rate helps determine whether cats have preferred travelling paths and whether these pathways overlap with the monitoring program.

Monitoring studies

Following trapping, we measure a number of indices of animal abundance using a variety of techniques, including distance sampling from spotlight transects, passive tracking plots and remote cameras. Spotlighting is performed along twelve 10 km transects. From a slow-travelling vehicle (10–15 km h^{-1}), we record the number of animals seen and their distance from the transect. For the passive tracking stations, 80 plots (swathes of loose soil raked across the road) set 1 km apart are checked for animal tracks and re-raked each day over three days. We also install 30 movement sensing remote cameras throughout the site for one-month periods.

Control studies

We then undertake ground shooting of foxes and cats at one site (Crowder's Creek), with indices recorded before and after shooting. The effectiveness of shooting as a control technique can be evaluated through values of the indices. Estimates of abundance should also be possible based on changes in the indices of abundance following removal.

This research is conducted under an animal ethics permit, CA 2007/09/214.

Progress in 2009–10

Movement studies

We trapped and collared 10 cats and 15 foxes with either GPS collars or conventional VHF radio collars. GPS collars were retrieved from three male cats. Each collar collected a minimum of 8 days of data, providing 2100, 1700 and 3100 locations respectively. For other cats and foxes with VHF collars, we recorded too few locations to enable home range analyses.

The average distance travelled within a 24-hour period by the three cats was 8 km,

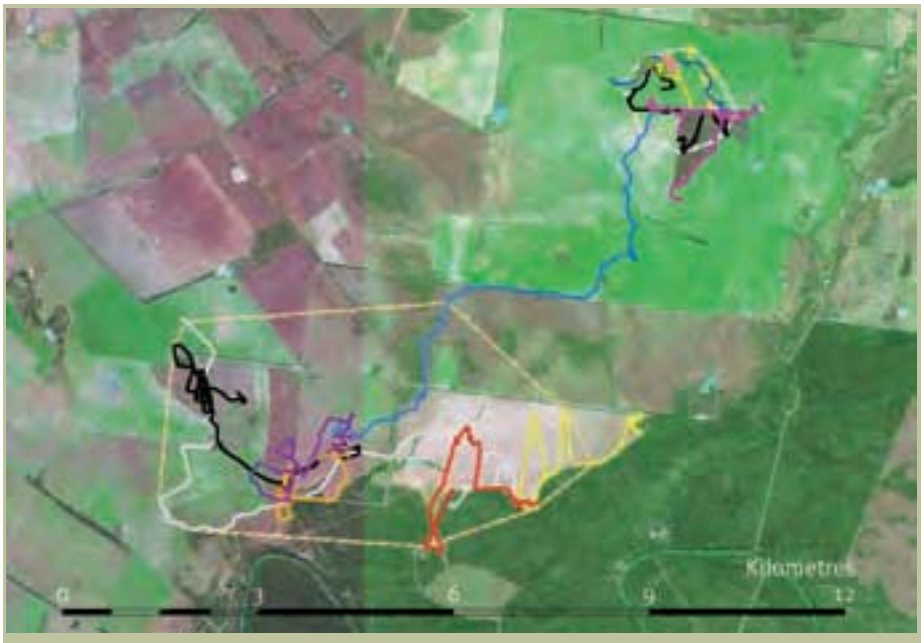

Figure 1. Thirteen daily tracklogs (coloured lines) of Cat 10, with each day one week apart. Dashed lines show two separate home ranges (95% minimum convex polygon) frequented by this cat.

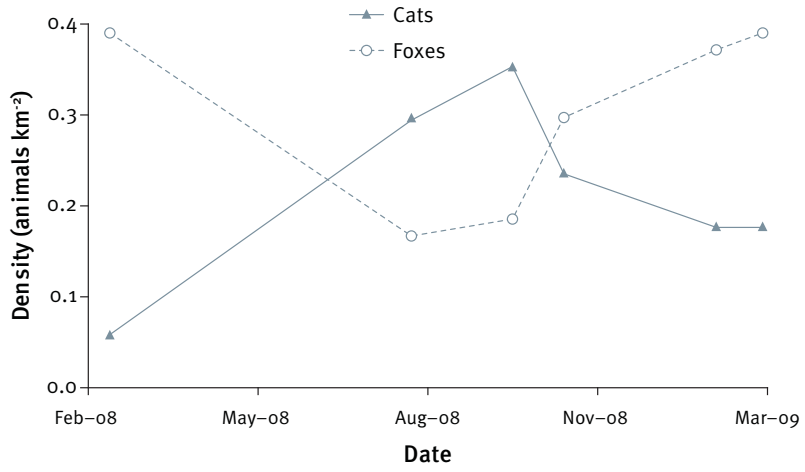

Figure 2. Density of foxes and feral cats determined by spotlight line transects.

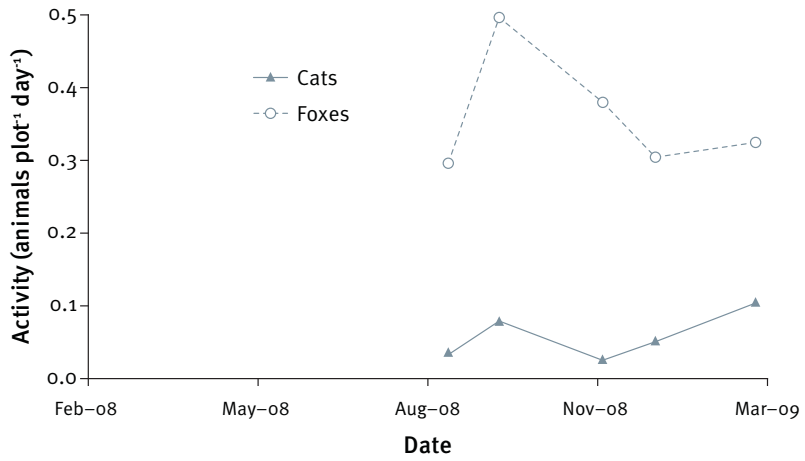

Figure 3. Activity of foxes and feral cats determined from footprints recorded on sand plots along roads.

the greatest distance travelled was >14 km and the shortest daily travel was 3.2 km. As can be expected, the cats were substantially more active at night (travelling 68% further), with the most active period between 10–11 pm. Daytime locations were generally recorded in woodland areas. Home ranges also varied between the cats [95% minimum convex polygon: 38 km^2 for Cat 10 (over four months, August–November 2008), 15 km^2 for Cat 1 (over five months, March–July 2008) and 10 km^2 for Cat 3 (over three months, April–June 2008)]. The home range of Cat 10 comprised two distinct areas (Figure 3), with one substantially overlapping the home range of a collared female cat. Further analysis of the use of different habitats by each cat, and determination of any preference for areas of travel, are still to be undertaken.

Monitoring studies

We completed a total of 720 km of spotlighting over six sampling occasions between February 2008 and March 2009. There were 93 sightings of foxes and 20 sightings of cats, suggesting densities of 0.17–0.39 and 0.06–0.35 animals km^{-2} respectively based on line transect sampling (Figure 1). Foxes were seen out to a perpendicular distance of 460 m from the track, with an estimated detection probability of 0.49 within a strip of 920 m. Cats were seen to a distance of 160 m, with an estimated detection probability of 0.44 within a strip of 320 m.

Activity of cats and foxes, recorded on passive tracking plots over five sampling occasions is shown in Figure 2.

Fox numbers were expected to increase from October (when cubs move out from dens) and then decrease after summer into the following winter. This pattern was reflected in the spotlight data but not in the activity data.

Cat density was negatively correlated with fox density ($r = -0.88$, $p < 0.05$). Again, the variation in the activity index over time did not match that reflected by the spotlighting data. However, given the low sample sizes, drawing any conclusion on population trends for cats using these techniques is difficult.

Camera data are yet to be analysed.

Control studies

During February–March 2009, we shot 49 foxes and 20 cats over 11 nights, involving 78 hours and 718 km of driving. This equated to about one animal per hour at roughly $30–35 per animal. 52% (49/92) of foxes seen were shot, with a success rate of 73% (49/67 foxes). Likewise, 52% of cats seen (20/38) were shot, with a success rate of 83% (20/24). Cats' tendency to 'hide and hope trouble will pass' was illustrated by the high success rate. In most cases cats sat still and provided a relatively easy target. However their ability to disappear into the landscape after an initial sighting (usually eye shine) before coming under rifle sight makes them difficult to shoot at longer ranges.

Foxes' tendency to be continually on the move made detection easier, but often shots were taken at moving animals and at greater distance, resulting in the lower success rate. Their ability to run out of range quickly was another factor.

Interestingly, the distance driven for shooting was almost exactly the same as the distance driven along the spotlight transects (718 km and 720 km respectively). An almost identical number of foxes was recorded (92 during shooting and 93 during spotlighting), whereas more cats were seen during shooting (38) than during spotlighting (20). This suggests that driving at a variable speed and through paddocks (as opposed to using tracks) may flush cats, yielding higher detection rates. Unfortunately, distances were not recorded during shooting so densities could not be

calculated and compared between the two survey methods.

Neither index of abundance showed a reduction following shooting. In fact, a slight increase in cat activity was recorded after shooting. This may reflect high immigration rates in the area, bias in the indices that were taken along roads, or that the monitoring techniques are insensitive to changes at low densities as confidence limits were broad [Spotlighting coefficient of variation (SE/mean) >0.24 (foxes) and >0.56 (cats)]. The causes are difficult to determine in the absence of a control site.

Diet

Analysis of the diet of cats and foxes is ongoing. So far, 53 cat and 122 fox stomaches have been examined. There is an obvious preference of cats for mammals, which comprise 89% by volume of their diet, but only 58% of the diet of foxes. Notably, invertebrates and carrion were a substantial component of the diet of foxes (16% and 20% respectively) while virtually absent in the diet of cats (Figure 4). This is consistent with the view that foxes are opportunistic feeders while cats are more selective.

Funding in 2009–10

Queensland Government (Blueprint for the Bush)

More information

For further information on this research project, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

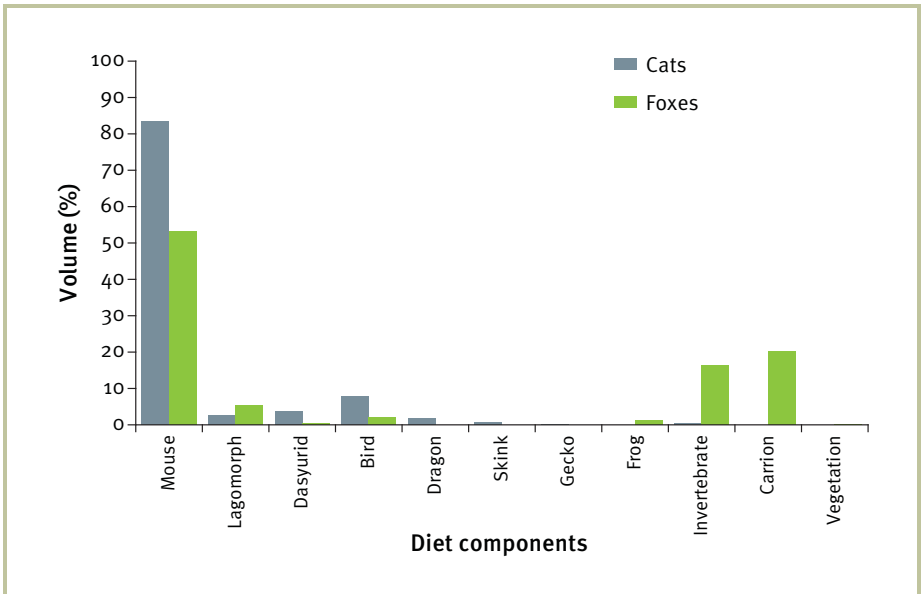

Figure 4. Composition by volume of the diets of 48 foxes and 20 cats shot on the study site in January 2009.

4. Development of a cyanide bait for monitoring feral pigs (*Sus scrofa*) and foxes (*Vulpes vulpes*)

Project dates

January 2007 – December 2010 (completed)

Project leader

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Other staff in 2009–10

David Aster and James Speed

Objectives

- Develop an effective formulation of cyanide for feral pig control to incorporate into current and potential bait substrates.
- Develop a delivery technique for baits containing cyanide.
- Demonstrate the efficacy of the bait on captive feral pigs and, if successful, undertake preliminary field trials to test efficacy.
- Conduct preliminary determinations of the delivery techniques for other species, particularly foxes.

Rationale

Feral pigs (*Sus scrofa*) pose a significant threat to livestock producers and public health as carriers of endemic and exotic diseases. Improved techniques for feral pig control, disease surveillance and sampling would be beneficial for exotic disease contingency planning and managing the impacts of this serious vertebrate pest.

Toxins currently registered for use in Australia have long latent periods, making them unsuitable for disease surveillance purposes. The use of potassium cyanide as a fast-acting feral pig toxin appears promising, as it would result in carcasses located close to the location where baits are consumed. This would be ideal for examining and collecting carcasses for disease sampling and generating population indices.

Methods

We trap feral pigs from wild populations in the Inglewood and Yelarbon districts of south-western Queensland and transport them to our research facility at Inglewood. All pigs are conditioned to the holding facilities for at least seven days. Pigs are maintained on a diet of commercial pig grower pellets and water is provided without restriction.

We present feral pigs with prototypes of each product to determine the nature and level of consumption. Initially, this involves testing non-toxic bait packages to determine if the product is consumed and the nature and level of consumption. A bait 'package' consists of a delivery product (or capsule) encased within the bait substrate. Pigs are presented with non-toxic versions of the package for sufficient periods to encourage their consumption of the toxic package when presented. We test toxic versions of the capsule for lethality only when the majority of pigs consuming the bait substrate also consumed the delivery product (the capsule designed to carry the toxin).

We conduct fox trials on agricultural properties in the Inglewood district to investigate potential cyanide formulations. Bait stations are provided with highly palatable food to encourage visitation and consumption by foxes before cyanide bait is added. We use remote cameras and spoor identification to confirm the identity of the animal that visited the plot and consumed the bait.

The research is conducted under an animal ethics permit CA 2010/05/438.

Progress in 2009–10

During the last 12 months, project collaborators Connovation Ltd have developed a new microencapsulated cyanide powder and a new mechanical delivery system. The encapsulated powder is intended to mask the detection of the cyanide powder to improve uptake and consumption of the bait. The improved delivery system within the ejector includes a synergist to accelerate cyanide gas release and resultant action of the toxin.

Emissions testing demonstrated that these new bait presentations were improvements over previously tested formulations. Trials on domestic pigs in New Zealand confirmed that pigs were more accepting and susceptible to the encapsulated cyanide than previous formulations. Furthermore, when the ejector

Photo 1. Captive feral pigs during pre-feeding for the cyanide wax bait trial at Inglewood.

system was activated it resulted in a quick death. Following these successful initial trials, two presentations were tested at Inglewood on captive feral pigs: 1) wax cylinder baits containing encapsulated cyanide and 2) the ejector delivery system.

The wax cylinder baits were largely unsuccessful at targeting feral pigs; only 4 out of 14 (28%) pigs succumbed following consumption of the bait. The remaining animals rejected the baits following partial consumption, with only 2 out of 10 (20%) showing any obvious symptoms of cyanide ingestion. None of the pigs managed to activate the ejector delivery system during the trials, despite interest in the attractant used.

The largely disappointing results indicate that significantly more research is needed to improve this technique before it could be considered for field deployment. While microencapsulation of cyanide powder appeared to offer some improvement in the initial acceptance of the wax baits, most pigs only partially consumed and rejected the cyanide. The ejector may require further technical modification to ensure deployment is consistent. Nevertheless, the difficulty in delivering a consistent lethal dose to feral pigs remains problematic and questions remain over whether cyanide is a suitable toxicant for feral pigs, given the issues with delivery, acceptance and toxicity.

We are currently preparing a publication on the applicability of cyanide for management of feral pigs. This will provide a valuable summation of, and suitable end point for, the current research.

Results for the fox field trials were reported in *Technical highlights 2008–09*.

Funding in 2009–10

- Queensland Government
- Invasive Animals CRC ($12 000)

Collaborators

Duncan MacMorran, Lee Shapiro, Charlie Eason and Paul Aylett (Connovation Ltd)

More information

Key publications

Aster, D., Boot, S. and Gentle, M. 2009. *Development of cyanide bait for rapid disease sampling and surveillance of wild animals*. Supplementary report. Wildlife and Exotic Disease Preparedness Program.

Gentle, M., Aster, D., MacMorran, D. and Eason, C. 2008. *Development of a cyanide pig bait for monitoring*. Final report. National Feral Animal Control Program, Bureau of Rural Sciences, Canberra.

For further information on this research project and access to key publications, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

5. Assessing the role of harvesting in feral pig (*Sus scrofa*) management

Project dates

January 2007 – December 2010

Project leader

Dr Matt Gentle
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Other staff in 2009–10

James Speed and David Aster

Objectives

- Survey landholders in the western Darling Downs to determine the distribution of pig damage, its perceived cost and the control methods employed.
- Estimate the density–impact relationship for pigs damaging grain crops.
- Quantify the effectiveness of commercial and recreational harvesting in managing feral pig populations.

Rationale

Pest managers often encourage commercial and recreational harvesting of feral pigs (*Sus scrofa*) because this is essentially a 'free' reduction in pest density. However, little is known about the effectiveness of such an approach in managing pig populations. Also, it is questionable whether Australian governments should remain passive observers in the commercial use of pest animals or pursue markets more actively and subsidise harvests in unprofitable areas or at unprofitable times.

This project is a critical component of an ongoing program by the Queensland Murray Darling Committee to coordinate the control of feral pigs, foxes and feral cats in the region. By evaluating the impacts of commercial and recreational pig harvesting compared to a coordinated control program, particularly in relation to crop damage, the project helps determine the optimum mix of harvesting and conventional control (i.e. baiting) and guide decision-making by pest managers.

Methods

We survey landholders using a combination of phone and postal surveys. In addition to identifying hot spots of damage and areas with little control, the survey facilitated the selection of study areas for more intensive assessments of damage and density. Importantly, these surveys also raise awareness of the project throughout the rural community.

We estimate both pig density and lost grain production using a combination of helicopter surveys and ground assessments. Pig damage and pig density are estimated on six study sites, predominantly grain-cropping properties. Study areas encompass a range of pig densities. These are monitored twice during the maturation of the crop—early (post-emergence) and at harvest. The aerial pig-density surveys are conducted using a four-seater helicopter (Robinson-44) flying along predetermined transects through each study area.

We assess pig damage by estimating the density of damage patches through line transect techniques and visually estimating the level of damage by comparing the yield within each damaged patch to the yield in an adjacent, undamaged crop area.

To monitor feral pig harvesting, we collate data from five wild boar processing companies on the number of pigs harvested locally from our study sites and regionally across Queensland. Processing companies record the number of pigs harvested from each of the 215 field chiller locations throughout Queensland, which allows an investigation of the spatial patterns in harvesting. We also collate aerial survey data collected as part of the annual macropod monitoring program (courtesy of DERM) to calculate feral pig densities at each of the Queensland survey blocks. We can then compare these feral pig densities with the numbers harvested by commercial companies to estimate the harvest rate over these large areas throughout Queensland. This requires the cooperation of individual harvesters, the game industry and Safe Food Queensland. We also monitor other control activities undertaken at each site through discussions with landholders.

This research is conducted under an animal ethics permit, CA 2007/09/211.

Progress in 2009–10

We completed two aerial surveys on all six study sites during the last 12 months to make a total of eight completed to date. Analysis of

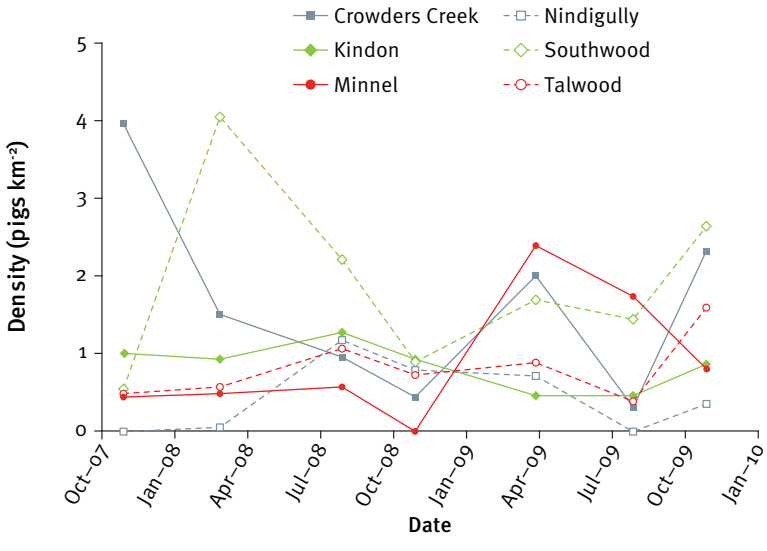

Figure 1. Feral pig density on the six study sites calculated from aerial surveys.

Photo 1. Typical feral pig damage to a wheat crop as seen a) pre-harvest by Experimentalist David Aster and b) post-harvest.

the first seven surveys (completed between November 2007 and November 2009) showed that feral pig density fluctuated seasonally within sites, but remained within approximately 0.5–4.0 pigs km^{-2} (Figure 1). Such densities appear typical of grain-producing areas and, interestingly, are similar to those recorded in 1985 in the same region (i.e. Bungunya, Billa Billa and Westmar) (Wilson *et al*. 1987).

We completed intensive ground assessments to monitor feral pig damage during the winter and summer cropping seasons. Little sorghum was planted on the project sites and thus few paddocks were available for sampling. However, damage was assessed across 32 wheat paddocks. Such surveys were labour-intensive; over 1500 km of walked transects were surveyed by staff to assess damage to wheat crops. While damage estimates from these surveys are yet to be calculated, damage levels appeared to be much less than those reported in earlier literature, at similar pig densities (e.g. up to 20% damage, Wilson *et al*. 1987).

Data collection on feral pig harvesting is continuing.

Funding in 2009–10

Queensland Government (Blueprint for the Bush)

Collaborators

- Queensland Murray Darling Committee
- Safe Food Queensland
- Australian Quarantine Inspection Service
- Game and meat processors

More information

References

Wilson, G.R., Hill, J.E. and Barnes, A. 1987. An aerial survey of feral pigs and emus in south-eastern Queensland. *Australian Wildlife Research* 14(4) 515–520.

For further information on this research project, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

6. Assessing feral pig (*Sus scrofa*) damage to crops using remote sensing

Project dates

February 2009 – December 2010

Project leader

Dr Matt Gentle
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Other staff in 2009–10

James Speed and David Aster

Objectives

Assess the use of satellite imagery and Geographic Information Systems to measure feral pig damage to grain crops. Key objectives are:

- Undertake field assessments of crops to identify and map areas of pig damage.
- Investigate methods for using satellite imagery and/or aerial photography to determine the extent of pig damage on grain crops.
- Given the success of objective 2, construct and validate a model to define pig damage from all available field data sets.

Rationale

Current methods to determine levels of feral pig (*Sus scrofa*) damage rely upon landholder surveys or intensive and costly field assessments. Surveys of landholders usually provide an indication of the level of damage perceived by landholders rather than actual measurements. The relationship between this subjective and usually qualitative measure and actual damage is unknown. However, quantitative assessments are very labour intensive and not practical for broadscale assessments of damage.

An earlier study by Caley (1993) investigated feral pig damage to sorghum and maize crops in the Northern Territory using a combination of exclosures and visual assessments to determine damage. Although these techniques were suitable for assessing damage to grain crops, Caley (1993) recommended that future studies should use aerial photography to quantify pig damage in sorghum crops. The use of satellite imagery is a logical extension of this recommendation. Satellite imagery offers the potential of determining the nature, extent and location of damage and its relationship with aspects of the environment.

Methods

Crops are surveyed on the ground for feral pig damage. Targeted crop types and paddock locations include those known to have historically suffered high levels of damage. We record the location of trampled patches (using a GPS), area and intensity of damage within this area (e.g. 80% loss), along with species responsible for the damage.

We use these data to establish characteristics of feral pig damage in crops, including the location and typical areal extent of pig damage. Such information is then used to specify a minimum mapping unit and image pixel size suitable for mapping pig damage. Initially, this allows us to select suitable image data from those available, including government archive SPOT, Ikonos, Quickbird or Geoeye.

Imagery (recorded at the same time as field data) is then analysed to determine unique characteristics of feral pig damage that can be used to develop a suitable mapping approach. Once we have developed a suitable approach, it may be applied to other current and archival imagery to identify areas of pig damage.

Progress in 2009–10

We have assessed a number of field crops (e.g. 32 paddocks were assessed in the winter 2009 growing season) for damage by feral pigs. From historic data (November 2008) we ascertained that most trampling damage by feral pigs is quite small in area (Figure 1), with the intensity of damage within each trampled patch ranging from 10% to 100%. As a result we identified and ordered the most suitable imagery for the required resolution—Quickbird with 0.6 m × 0.6 m pixels.

The field survey data and corresponding spatial data were supplied to our collaborators at UQ to develop a suitable mapping approach. Initial analyses of the field data suggest that it may difficult to identify pig damage in grain crops from satellite imagery. There was no apparent match between survey points and evident damage in the images. The characteristics of trampled patches in wheat crops appear difficult to distinguish

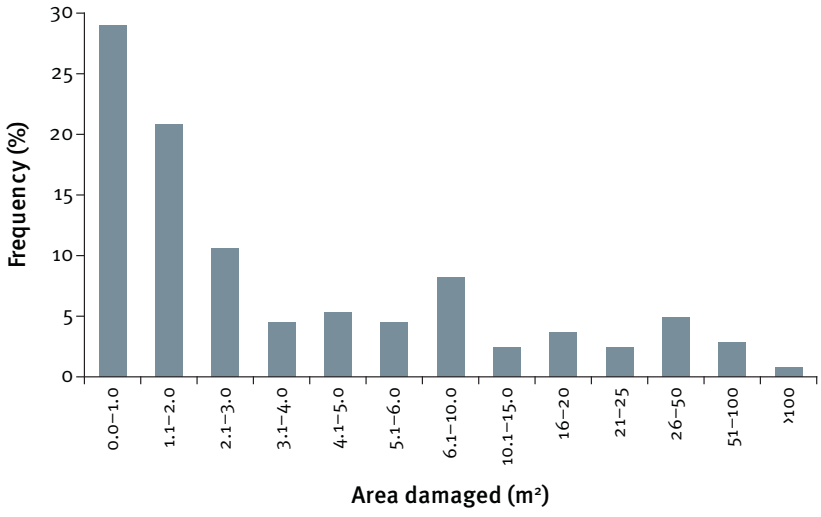

Figure 1. Frequency of various classes describing the area damaged by feral pigs across all assessed wheat paddocks in southern Queensland, November 2008.

Figure 2. Waypoints indicating locations of feral pig damage in a wheat crop at Southwood in southern Queensland.

from underlying damage, including poor crop strike, wind and scalding, which are all typical of dryland cropping systems. Further refinement of the approach may improve our ability to classify pig damage.

Funding in 2009–10

- Queensland Government
- Australian Pest Animal Management Program, DAFF ($67 000)

Collaborators

Prof Stuart Phinn (Centre for Spatial Environmental Research, UQ)

More information

References

Caley, P. 1993. *The ecology and management of feral pigs in the 'wet-dry' tropics of the Northern Territory*. MAppSci Thesis. University of Canberra, Canberra.

For further information on this research project, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

7. Feral pig (*Sus scrofa*) impacts on freshwater ecosystems

Project dates

June 2007 – June 2010 (completed)

Project leader

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Other staff in 2009–10

Bill Dorney

Objectives

- Use a number of ecological indicators found in freshwater habitats as a guide to quantifying feral pig impacts on elements of biodiversity.
- Conduct large-scale, 'learning-by-doing' manipulative experiments to describe the feral pig abundance/impact system so that management strategies can be developed.

Rationale

Environmental impacts of feral pigs (*Sus scrofa*) have not been studied intensively and very little quantitative information is available on the ecological impacts feral pigs cause throughout Australia. There is a distinct lack of information on a number of threatened ecosystems and, in particular, there is a scarcity of information relating to seasonal freshwater habitats in the dry tropics. This study aims to assist in answering questions relating to feral pig impacts on this unique habitat.

Methods

The research site is situated in Lakefield National Park—specifically the area surrounding the New Laura ranger station (15.175° S, 144.348° E).

There are two studies:

Ecological impact of feral pigs on biodiversity

We construct exclusion fencing consisting of feral pig netting around four ephemeral lagoons and billabongs. Four lagoons with approximately the same surface area, depth, etc., act as experimental controls, where feral pig access is unrestricted. Comparisons of ecological indices obtained over the dry seasons from fenced and unfenced lagoons provide an indication of the ecological damage attributable to feral pigs. We obtain ecological indices at two month intervals, dependent on weather conditions.

Relationship of ecological impact to feral pig density

We use aerial shooting to artificially manipulate the population density of feral pigs around selected large lakes in the area to enable the quantification of feral pig damage in sites that have varying pig abundance levels. There are four treatments based on the relative abundance of pig populations on each lake (i.e. Caulders Lake—low pig population, Jacks Lake—low to medium pig population, North Kennedy Lake—medium to high pig population, Broads Lagoon—control with normal pig population for this area). We describe the pig population levels from a series of abundance indices derived at two month intervals during the survey period. For each lake, we conduct a systematic sampling regime for the ecological indicators to determine the impacts of pig abundance.

Progress in 2009–10

Overall, feral pig activity had a negative impact on the ecological condition of ephemeral lagoons, with the major impacts related to destruction of habitat and reduction in water clarity. Pig foraging activities caused major destruction to aquatic macrophyte communities—their preferred food resource. We observed dramatic differences in the proportion of bare ground and aquatic macrophytes between protected and unprotected lagoons; protected lagoons had significantly more macrophyte coverage. The destruction of macrophyte communities and upheaval of wetland sediments in unprotected wetlands significantly reduced water clarity and had subsequent effects on key water quality parameters such as dissolved oxygen. Other water quality parameters, such as nutrient levels, were also affected by pig activity; although the differences were not statistically significant, it appeared that pig activity contributed to an increase in nutrient levels in the unprotected lagoons.

Our manipulative experiments showed a positive association between pig abundance (visitation frequency and digging frequency) and extent of impact (digging area); impact increased exponentially with pig abundance. This means when pig abundance is high, a minimal level of population control will substantially reduce impacts. Conversely, when pig abundance is low, a substantial level of population control will only marginally decrease impact levels. Our data suggest that control activities may be most effective in reducing impacts at abundance levels above 50% visitation frequency.

There was also a significant positive association between the Aquatic Vegetation Index and two pig abundance indices; pig abundance increased with increasing aquatic vegetation abundance. This suggests that pigs may concentrate their impacts to areas where adequate resources are available.

On transects, 0.93% of the soil surface was disturbed by pig diggings on a daily basis. Thus, hypothetically, the total perimeter of the studied wetlands would be disturbed by feral pig diggings in just over 100 days.

We further collected stomach and colon contents of 95 feral pigs from around Caulders Lake. Overall composition of the diet for all seasons was 48% water lily bulb and nonda plum (*Parinari nonda*), 43% leaf and stem, 8% seed, 0.56% vertebrate matter and 0.47% invertebrate matter. Diet composition was related to seasonal conditions for all diet categories. Plant matter was present in all diets, while animal matter occurred in 87% of diets. These results suggest that feral pigs at Lakefield National Park may have an ecological impact on water lilies, nonda plum

trees and snails, and indirect effects on the comb-crested jacana (*Irediparra gallinacea*).

Funding in 2009–10

- Queensland Government
- DEWHA ($20 000)

Collaborators

- James Cook University, Australian Centre for Tropical Freshwater Research
- DERM

More information

Key publications

Mitchell, J. 2010. *Experimental research to quantify the environmental impact of feral pigs within tropical freshwater ecosystems*. Final report to the Department of Environment, Water, Heritage and the Arts, Canberra. 125 pp.

Doupé, R.G., Mitchell, J., Knott, M.J., Davis, A.M. and Lymbery, A.J. 2009. Efficacy of exclusion fencing to protect ephemeral floodplain lagoon habitats from feral pigs (*Sus scrofa*). *Wetlands Ecology and Management* 18(1): 69–78.

For further information on this research project and access to key publications, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

8. Adaptive management of rabbits (*Oryctolagus cuniculus*) in south-eastern Queensland

Project dates
2000 – 2012

Project leader
Dr David Berman
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Other staff in 2009–10
Michael Brennan

Objectives
Establish landholder-driven, scientifically-monitored rabbit control programs in the DDMRB area to:

- measure the benefits of rabbit control to biodiversity, agriculture and pastoralism
- demonstrate the importance of targeting control activities in key breeding places (sources)
- refine control strategies and methods to reduce cost and increase effectiveness
- measure the cost of eradicating small, isolated rabbit populations.

Rationale
In south-eastern Queensland, a rabbit-proof fence maintained by the DDMRB has protected large areas from rabbits since 1906. This area is unique because it is highly suitable for rabbits, yet has never experienced the damage caused by plagues of uncontrolled rabbits as seen in adjacent areas not protected by the rabbit-proof fence. This situation is ideal for measuring the benefits of effective rabbit control to biodiversity and agriculture. Measuring these benefits and demonstrating control methods are essential to justify the expense of controlling rabbits and to encourage landholders to control this pest. Targeting key warrens or 'source areas' has the potential to minimise the cost of rabbit control and maximise its long-term effectiveness in south-eastern Queensland.

Methods
The study site is located at Cottonvale on the southern edge of Warwick Shire and has a high concentration of rabbit warrens within 500 m of the area protected by the rabbit-proof fence. Breaches in the fence have allowed some rabbits into the rabbit-free area but they have not established warren systems there; these animals live in log piles. Soil type, landform and land use are similar on both sides of the fence.

We mark all warrens and log piles with steel posts and record the number of active and inactive burrows. We also establish rabbit-proof and cattle-proof (with rabbit access) exclosures to identify the impact of rabbits and separate this from impacts caused by cattle. To monitor rabbit and wildlife activity, we distribute sand tracking plots and also install movement sensing cameras. Once the differences are measured between lightly infested and heavily infested areas, we destroy warrens by ripping and measure its effectiveness for rabbit control and the associated rate and extent of recovery of pasture and biodiversity.

Progress in 2009–10
Measurements have been conducted inside and outside the rabbit-proof fence since 2007. Results indicate that the 'dirty' side is characterised by a high number of warrens, high density of rabbits as well as foxes, fewer pasture species and low macropod activity. Echidna and bandicoots were recorded on the 'clean' side but not on the 'dirty' side of the fence.

After warren ripping was completed, rabbit numbers were low on both sides of the fence. There was a rapid drop in the number of foxes photographed on the 'dirty' side of the fence and an increase on the 'clean' side (Figure 1), suggesting that the reduction in rabbit numbers due to ripping caused the foxes to seek hunting grounds elsewhere. Monitoring of post-ripping macropod activity and changes in pasture composition is continuing.

Funding in 2009–10
Land Protection Fund ($259 000)

Collaborators
- Mark Ridge (DDMRB)
- Shane Cartwright (Queensland Murray Darling Committee)
- Harley West (Granite Borders Landcare)

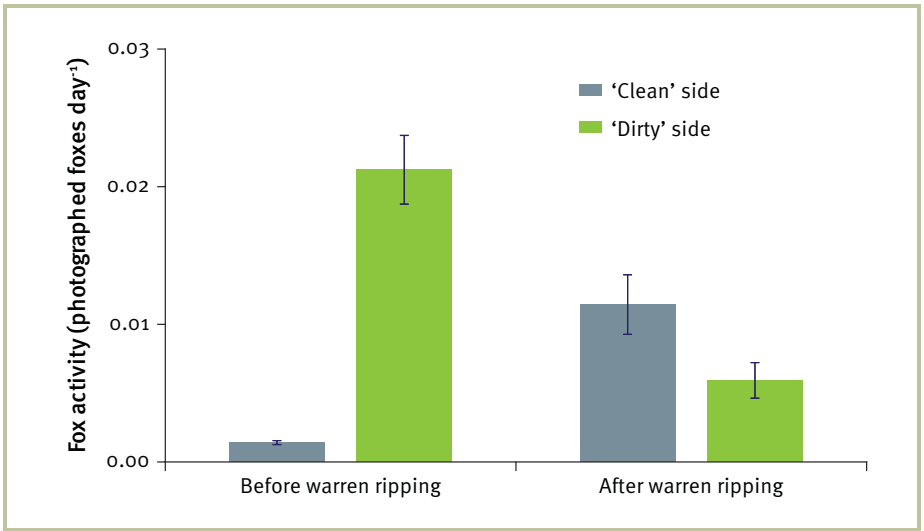

Figure 1. Fox activity on the 'dirty' and 'clean' sides of the rabbit-proof fence before and after warren ripping. (Vertical bars indicate the SE of the means.)

More information

Key publications

Brennan, M. and Berman, D. 2008. The value of having no rabbits in South East Queensland. In: *Proceedings of the 14th Australasian Vertebrate Pest Conference*. G. Saunders and C. Lane, eds. The Vertebrate Pests Committee and the Invasive Animals Cooperative Research Centre, Canberra, ACT. p. 102.

Scanlan, J.C., Berman, D.M. and Grant, W.E. 2006. Population dynamics of the European rabbit (*Oryctolagus cuniculus*) in north eastern Australia: simulated responses to control. *Ecological Modelling* 196(1-2): 221–236.

For further information on this research project and access to key publications, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

9. Mapping distribution and density of rabbits (*Oryctolagus cuniculus*) in Australia

Project dates

July 2008 – November 2011

Project leader

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Other staff in 2009–10

Michael Brennan

Objectives

- Improve understanding of the distribution and abundance of rabbits in Australia.
- Produce a map of the distribution and abundance of rabbits suitable for:
  - estimating the extent of damage caused
  - efficiently planning control programs
  - monitoring the success of rabbit control at the regional, state and national levels.

Rationale

From an initial release in Victoria in 1859, European rabbits (*Oryctolagus cuniculus*) have spread across the country and are viewed as Australia's most serious vertebrate pest. During the past 60 years, rabbit populations have been suppressed significantly by the biological control agents myxoma virus and RHDV, and (in places) by conventional control. Yet, it is difficult to measure the benefit of these control efforts because our knowledge of rabbit distribution and abundance Australia-wide has been inadequate.

A map prepared as part of the National Land and Water Resources Audit 2007 was based on predominantly qualitative information obtained from local experts, which makes comparisons between regions difficult.

A map prepared for Queensland using Spanish rabbit flea release sites and soil type (Berman *et al.* 1998) proved a good representation of rabbit density and distribution, but its extension to the whole of Australia was compromised by data restricted largely to arid areas.

In order to collect recent rabbit distribution and abundance data across all of Australia, the Rabbit Management Advisory Group initiated RabbitScan in May 2009. RabbitScan gives all Australians a means to map rabbits using Google Earth technology. It is designed to allow community and school groups to report rabbit abundance. Records collected by RabbitScan, combined with existing records, will provide an improved understanding of rabbit distribution in Australia.

Methods

We provide scientific support for RabbitScan, promote the collection of data via RabbitScan and search for published and unpublished historical records of rabbit occurrence and density. Using all available records of rabbits (historical and RabbitScan), we determine the density of rabbit sites across various soil landscapes (as classified in the Atlas of Australian Soils mapping units). This enables us to produce a map showing the relative suitability of areas for rabbits.

We also investigate whether there is evidence for expansion in the range of rabbits. For this, we overlay historical and RabbitScan data points (including a 20 km buffer representing the area immediately threatened by dispersing rabbits).

Progress in 2009–10

Between May and November 2009, 3215 RabbitScan sites were recorded, with rabbits present at 2979 of these sites. From RabbitScan and other sources we have obtained coordinates for a total of 9901 points where rabbits occur or have occurred in Australia. A map showing the relative suitability of areas for rabbits is presented below (Figure 1). Assuming suitability for rabbits remains constant, this map should accurately represent the distribution and abundance of rabbits in Australia. However, suitability has changed due to changed agricultural practices, degradation of pasture, introduction of biological control and other control activities. It is important to obtain a larger number of recent points representing all parts of Australia to produce a map that better reflects the current distribution and abundance of rabbits.

RabbitScan has also improved our knowledge of the extent of damage caused by rabbits. Damage to tree seedlings or shrubs was reported at 2861 sites and this damage increased with increasing rabbit density.

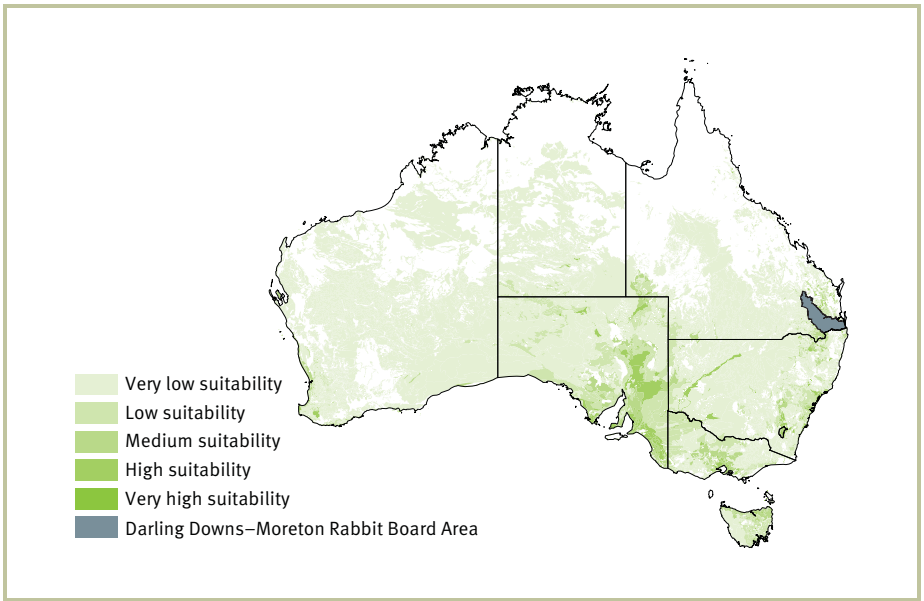

Figure 1. Relative suitability of areas for rabbits in Australia based on the density of recorded rabbit locations in each of the Atlas of Australian Soils mapping units.

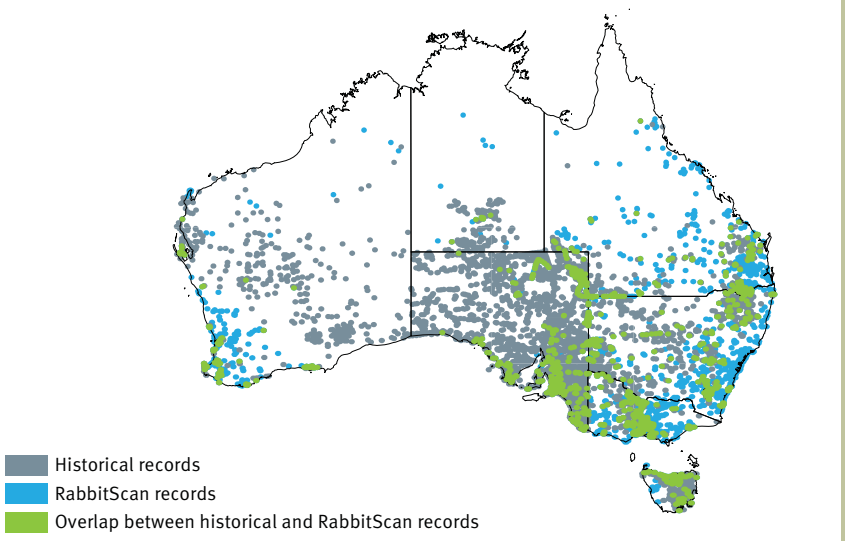

Figure 2. Area exposed to the impact of rabbits in Australia, both historically and as reported via RabbitScan. (Data points are surrounded by 20 km buffers representing the area immediately threatened by dispersing rabbits).

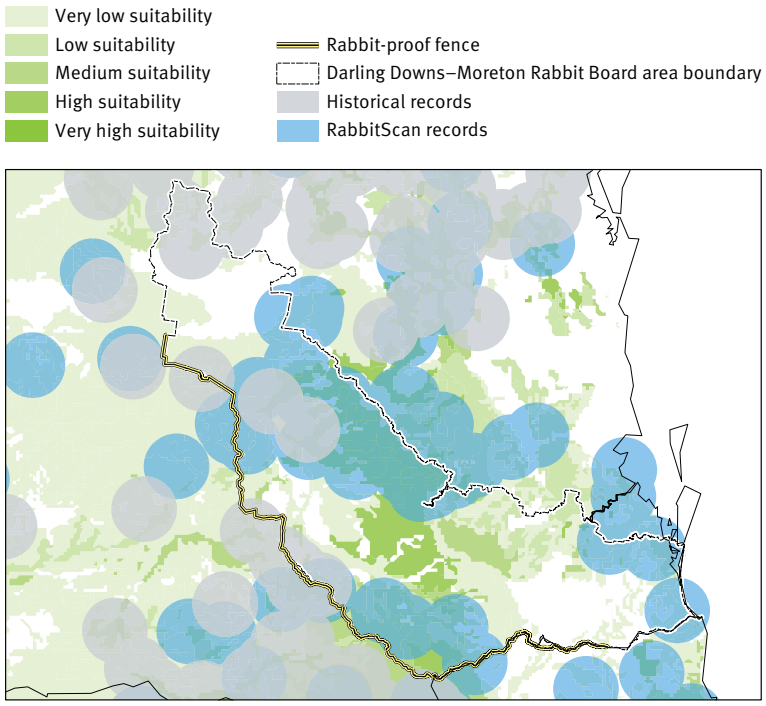

Figure 3. Area exposed to the impact of rabbits in south-eastern Queensland, both historically and as reported via RabbitScan, overlayed with a map showing relative suitability of areas for rabbits. (Data points are surrounded by 20 km buffers representing the area immediately threatened by dispersing rabbits. Dark green areas represent soils most suitable for rabbits, where future spread is most likely.)

Comparison of historical and RabbitScan records indicates that the total area exposed to the impact of rabbits has increased by approximately 550 000 km^2 (Figure 2). This increase may be due to an expansion in the range of rabbits and/or an increase in our knowledge of their distribution. Without more detailed local knowledge it is difficult to determine whether there has been an expansion of rabbit range. In South Australia, where there was a good coverage of historical records, there is very little increase in the area threatened by rabbits. Perhaps in many other parts of Australia we had an inadequate number of historical points and RabbitScan has begun to fill the gaps in our knowledge.

Nevertheless, one obvious area with an expanding rabbit population is in south-eastern Queensland. Landholders have first reported rabbits appearing in this area in the last 5–10 years. This has occurred most notably in the DDMRB area where a rabbit-proof fence and rabbit control activities had prevented rabbits from establishing for over 100 years. Historical data from this area stem from rabbit warrens where Spanish rabbit fleas were released in the early 1990s. To increase validity of comparisons, we have used only RabbitScan points where warrens were present. The resulting map (Figure 3) illustrates a recent increase in the area threatened by rabbits. This movement of rabbits, particularly from the north, is a severe threat to the DDMRB area. Increased control efforts are required to prevent further invasion and remove rabbits from this area.

This work highlights the importance of mapping the distribution and abundance of rabbits for identifying areas that require increased control efforts. RabbitScan will continue as part of a new project called FeralScan (www.feralscan.org.au/rabbitscan) in which other pest animals will also be mapped. The full value of RabbitScan will be realised once a few years of data have been collected and we can look at trends in areas with or without rabbit control activities.

Funding in 2009–10

Land Protection Fund

Collaborators

- Rabbit Management Advisory Group
- Brian Cooke (Invasive Animals CRC; University of Canberra)
- Damien Fordham (The University of Adelaide)
- Grant Hamilton and Melissa Paton (QUT)

More information

Key publications

Berman, D. and Cooke, B. 2008. A method for mapping the distribution and density of rabbits and other vertebrate pests in Australia. In: *Proceedings of the 14th Australasian Vertebrate Pest Conference*. G. Saunders and C. Lane, eds. The Vertebrate Pests Committee and the Invasive Animals Cooperative Research Centre, Canberra, ACT. p. 103.

Berman, D., Robertshaw, J. and Gould, W. 1998. Rabbits in Queensland: where have they been, what have they done and where are they now? In: *Proceedings of the 11th Australasian Vertebrate Pest Conference*. Bunbury, Western Australia. pp. 395–399.

For further information on this research project and access to key publications, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

10. Resistance to rabbit haemorrhagic disease virus in Australian rabbits (*Oryctolagus cuniculus*)

Project dates

July 2007 – December 2011

Project leader

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Other staff in 2009–10

David Berman and David Aster

Objectives

- Develop a test protocol for determining resistance to RHDV in rabbits.
- Test rabbits from around Australia to determine if resistance is developing and to what level it has developed.
- Explore reasons behind variation in any resistance seen between populations.
- Test field strains of RHDV to compare virulence and effectiveness against the original release strain.
- Explore interactions between RHDV and the new suspected benign rabbit calicivirus (RCV-A1) discovered in Australian rabbits.

Rationale

RHDV has been a successful tool in the control of rabbits (*Oryctolagus cuniculus*) throughout Australia. It caused a great reduction in rabbit numbers on initial release and continues to keep numbers low in many areas. However, concerns have been raised about RHDV's continuing efficacy, as numbers of rabbits are increasing in some areas. Rabbits started showing resistance to myxomatosis about 10 years after its initial release and it has now been over a decade since RHDV was released. Anecdotal and observational information indicate rabbit numbers are increasing to levels not seen since the release of RHDV. Monitoring sites have also shown changes in rabbit populations during outbreaks of RHDV that may indicate the development of resistance. Rabbits are a major pest of agricultural and natural systems and if they were to return to the numbers present pre-RHDV, they would once again have a devastating effect.

Initial challenge tests showed that different populations of rabbits around Australia had differing levels of resistance to RHDV. The level of resistance was correlated to rainfall, with populations from regions of intermediate rainfall having the highest resistance levels. As rabbits develop resistance, changes in the virus to overcome this resistance can also be expected. It is therefore necessary to examine the virulence of field strains of RHDV to assess its on-going efficacy.

Methods

We obtain field-strain virus from the Turretfield area in South Australia. Virus has been collected from this area every year since RHDV was released. The Department of Water, Land and Biodiversity Conservation (South Australia) performs phylogenetic analyses to establish how much the virus may have changed over time. Virus is standardised using ELISA titration and real-time PCR.

A series of challenge tests against a standard line of rabbits allows comparison of various field strains against the original release strain of RHDV. Survivors of those trials are allowed to breed and their offspring is tested. If resistance is genetically-based, offspring should have a higher resistance level than the parent generation and each subsequent generation bred from survivors should have increasing resistance levels.

Progress in 2009–10

We sourced field-strain virus from the Turretfield area in 2006, 2007 and 2009. Trials showed that the field strains of RHDV collected from the Turretfield area in South Australia are maintaining a relatively high level of virulence. The 2007 and 2009 strains caused 100% mortality, while the 2006 strain caused 90% mortality and the original release strain 75%. The survival times of rabbits followed a similar trend, with the 2007 and 2009 strains leading to death within 50 hours while the 2006 strain took 81 hours and the original release strain 130 hours.

These results highlight the dynamic coevolution between rabbits and RHDV at this site, as the Turretfield rabbits are relatively resistant to the original release strain, but not to the field strains actively circulating in that population. From a management view, this shows that RHDV is still controlling rabbits in the Turretfield area, but re-release of the original strain may not be effective.

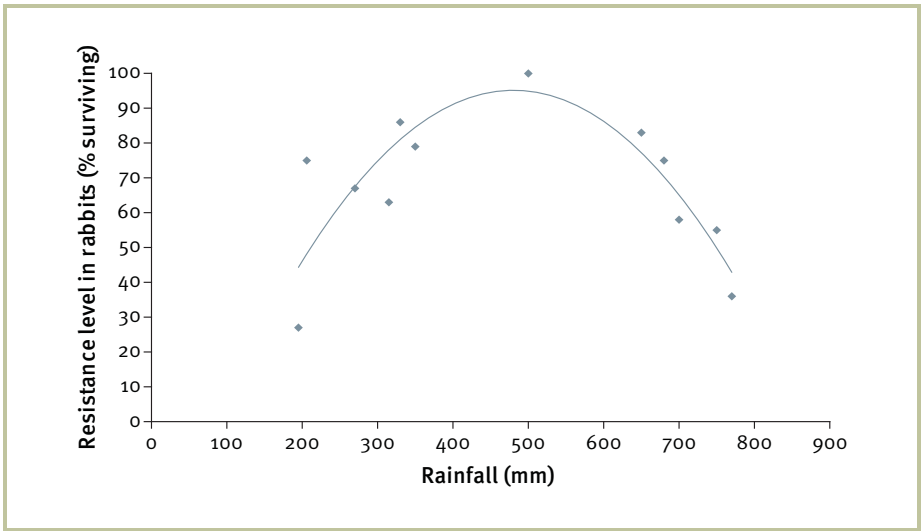

Figure 1. Level of resistance to RHDV observed in rabbit populations sourced from regions with varying rainfall levels.

We have also sourced wild rabbits from Bulloo Downs in south-western Queensland, as well as domestic control rabbits, and bred a first generation in preparation for challenge tests to establish whether resistance does indeed have a genetic basis.

Funding in 2009–10

- Queensland Government
- Invasive Animals CRC ($15 000)

Collaborators

- Brian Cooke (Invasive Animals CRC; University of Canberra)
- Greg Mutze, Ron Sinclair and John Kovalivski (Department of Water, Land and Biodiversity Conservation, South Australia)

More information

Key publications

Cooke, B.D., Elsworth, P.G., Berman, D.M., McPhee, S.R., Kovalivski, J., Mutze, G.J., Sinclair, R.G. and Capucci, L. 2007. *Rabbit haemorrhagic disease: wild rabbits show resistance to infection with Czech strain 351 RHDV initially released in Australia*. Report submitted to the Australian Wool Innovations and Meat and Livestock Australia. Invasive Animals Cooperative Research Centre, Canberra.

Story, G., Berman, D., Palmer, R. and Scanlan, J. 2004. The impact of rabbit haemorrhagic disease on wild rabbit (*Oryctolagus cuniculus*) populations in Queensland. *Wildlife Research* 31(2): 183–193.

For further information on this research project and access to key publications, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

11. Effective and safe rodent management

Project dates

April 2006 – June 2010 (completed)

Project leader

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Other staff in 2009–10

James Speed

Objectives

- Identify potential rodenticides as alternatives to the single registered chemical available for use in grain crops in Australia.
- Refine plague prediction models for mice on Queensland grain farms.

Rationale

Mice (*Mus domesticus*) and rats (*Rattus* and *Melomys* spp.) cause considerable annual losses to Australian agriculture, particularly grain production. Plagues occur on average every 3–4 years in Queensland, which is roughly twice the frequency experienced in crops in southern Australia. Grain producers are concerned that there is only a single rodenticide, zinc phosphide (ZnP), registered for broadacre use. This is considered a risk, as regulators may place restrictions on the rodenticide's use because it is a hazard to children and pets, phosphide residues in grain could lead to an export ban and bait aversion in mouse populations may reduce efficacy. Zinc phosphide bait for mice has, until recently, been supplied by a single manufacturer and there is also concern that the manufacturers may be unable to maintain supply for a number of reasons.

As part of this project, laboratory trials determined that three of four alternative rodenticides (bromethalin, encapsulated zinc phosphide, cholecalciferol, but not diphacinone) can cause high mortalities of mice even when alternative food is available. Some rodenticides degrade when left out in the weather. However, weathered bromethalin and cholecalciferol baits were still toxic to mice after five days, again causing high mortality. In addition, no detectable residues of zinc phosphide or bromethalin were found in grain or other plant material following application, at 100 times the recommended rate, on representative summer and winter crops in the glasshouse.

Field assessment of baits showing promise in the cage trials is an important next step, providing information on efficacy and ideally non-target impacts. In contrast to laboratory trials, where animal behaviour can be highly modified due to captivity and possibly selective breeding, field trials provide an unrestrained environment where mice are exposed to a wide range of food, experience intraspecific competition and interact with other species. However, field trials are notoriously logistically difficult to undertake and the resultant data often difficult to interpret through considerable environmental noise. Further, there was a protracted delay in obtaining permits from the APVMA to undertake a field trial. A decision was therefore made to undertake trials in field enclosures at UQ, Gatton, for which APVMA were prepared to issue a permit. Field enclosures have the advantage of controlling mouse density and other factors that can confound the results of an open field trial.

In 2008, Bell Laboratories submitted a registration package for the ZnP pellet, so field trials for this bait were not required. Despite promising laboratory results, bromethalin was no longer considered a candidate as it is a relatively new rodenticide with little public information and no registration in Australia: reasons for APVMA not issuing a permit for a field trial. In contrast, cholecalciferol is a well-known rodenticide registered for use around buildings in Australia and so was pursued in the field trials along with two new cholecalciferol baits from Connovation Inc., New Zealand. Some future assessment in the field may still be required, particularly for non-target impacts.

Models predicting mouse plagues from rainfall enable growers to plan future management strategies to reduce crop losses. Bait manufacturers also require lead time to provide sufficient bait to suppress developing plagues. Government agencies will also benefit from a warning of a pending pest outbreak as they can plan logistic and technical support. A model exists for the central Darling Downs, but there is now a longer time series and data from other sites that allow further evaluation of the model. Trapping has also been conducted along two transects in central Queensland with the data modelled relatively unsuccessfully in the past. The longer time series again warrants further assessment of the data. The key questions are whether, firstly, mouse abundance recorded on the transects alone provides a warning system for mouse numbers over a broader area and, secondly, whether models derived from these data provide similarly useful predictions of pending mouse damage to crops.

Methods

Rodenticide field trials

A wheat crop is grown in 16 large (15 m × 15 m) enclosures where known densities of mice were released and then baited. We assess the cholecalciferol bait from the cage trial along with the currently registered ZnP bait, a lower-dose cholcalciferol bait (Connovation Inc.), a combined cholecalciferol and coumatetralyl bait (C+C) (Connovation Inc.) and a non-toxic control bait. We also collect plant material for assessment of potential toxin residues.

Modelling

Regular trapping of mice at the same sites on the Darling Downs in southern Queensland has been undertaken since 1974. This has provided an index of abundance over time that can be related, using regression models, to rainfall, crop yield and area, winter temperature and past mouse abundance. We use time series analysis to test for trends in mouse abundance over time. Other sites have been trapped over a shorter time period elsewhere on the Darling Downs and in central Queensland, allowing a comparison of mouse population dynamics among sites and cross-validation of models predicting mouse abundance.

Progress in 2009–10

Rodenticide field trials

The survival of mice in enclosures treated with ZnP bait and C+C differed significantly from the survival of mice in the control enclosures, indicating that these baits are effective. However, the observed mortality was lower than that generally required for registration of rodenticide bait. The survival of mice in enclosures treated by the two cholecalciferol baits was not significantly lower than the survival of mice in the control pens, indicating that these baits are not effective. The trial was undertaken in a maturing wheat crop and greater efficacy may have been achieved in an immature crop. Efficacy could also be improved by spreading bait at night, as only 30% of ZnP bait and 15% of C+C bait remained on the ground one hour after baiting around sunset, most likely due to removal by ants. The density of mice did not significantly affect efficacy. The data are encouraging for grain growers who may need to control mice in mature crops. Further, while registration of C+C bait may not be supported by these data alone, the bait shows promise and so additional data on its efficacy in immature crops would be worthwhile.

Modelling

On the regularly trapped transect on the Darling Downs, damaging mouse densities occur every second year and a plague every four years, but there has been no detectable increase in mouse abundance over the past 35 years (Figure 1). High mouse abundance on this transect is not consistently matched by high abundance in the broader area, even for nearby locations, so monitoring the transect does not provide a warning system for the Darling Downs. However, a predictive model developed from the transect data can forecast future mouse abundance at a particular location. Local (i.e. farm-based) monitoring of mouse abundance in spring can indicate the potential for an outbreak in autumn–winter as part of a model rather than using unreliable thresholds such as >1% trap success in spring leading to an outbreak. New models, with and without spring mouse abundance, can predict autumn–winter mouse abundance (i.e. the annual maxima), but there are false positives and negatives. These models include autumn–winter rainfall in the previous year, overlooked as a predictor of mouse abundance in previous analyses, but well recognised as an important predictor of mouse abundance in cropping areas in southern Australia.

In central Queensland, mouse population dynamics contrast with those on the Darling Downs in lacking the distinct annual cycle, with peak abundance occurring in any month outside early spring. On average, damaging mouse densities occur every three years and a plague every seven years. The dynamics of mouse populations on two transects ~70 km apart were rarely in parallel (Figure 2) and so, again, any early warning must come from local monitoring at the scale of a farm. Autumn–winter rainfall offers a useful indicator of mouse abundance in some seasons, but there is no single model to predict mouse abundance for all areas within the region.

Funding in 2009–10

- Queensland Government
- Grains Research and Development Corporation ($10 000)

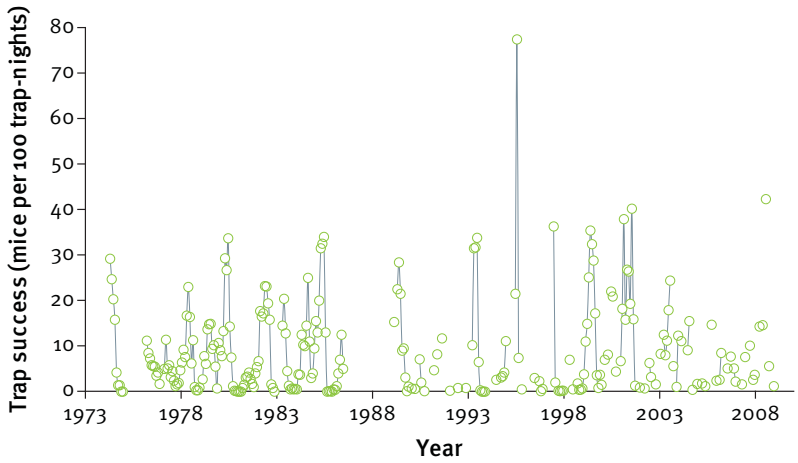

Figure 1. Monthly trap success along a 32 km transect in the central Darling Downs, comprising 47 sites, each with 20 break back traps. Values for consecutive months are connected by lines. Mouse damage tends to occur at densities above 20% trap success.

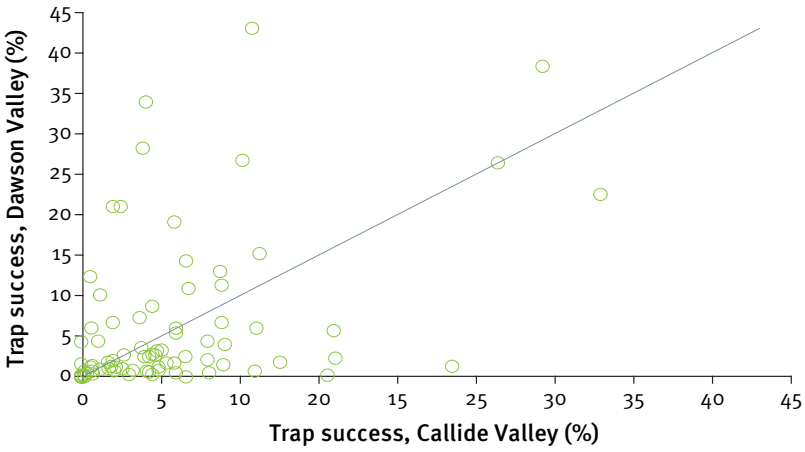

Figure 2. Monthly trap success for house mice recorded over 1998–2008 on a transect (comprising 22 sites, each with 10 break back traps) in the Dawson Valley, compared with corresponding months on a similar transect in the Callide Valley (~70 km away), both in central Queensland. High, damaging densities (>20% trap success) were matched in only three of ten cases. The straight line is y = x.

Collaborators

- Bell Laboratories Inc.
- Animal Control Technologies Australia
- Connovation Ltd, New Zealand
- Grain farmers
- Luke Leung (UQ—through UniQuest)

More information

Key publications

Pople, A.R., Cremasco, P., Parker, R. and Leung, L. 2010. *Effective and safe rodent management in grain cropping systems*. Final report to the Grains Research and Development Corporation, Canberra.

For further information on this research project and access to key publications, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

12. Testing feral deer (*Cervus timorensis*) control in the wet tropics: enabling a response to future complaints and increasing impacts

Project dates
July 2008 – December 2009 (completed)

Project leader
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Other staff in 2009–10
Jim Mitchell

Objectives
- Identify techniques suitable for feral deer capture.
- Investigate different monitoring techniques to quantify the success of control efforts.
- Establish a good network of community contacts to report deer sightings.
- Support and increase the capacity of Biosecurity Queensland officers, local government officers and other government agencies responsible for land management (e.g. DERM/QPWS) to facilitate deer control programs in the region.
- Incorporate all results into extension information and a final report/case study.

Rationale
Small discrete populations of feral rusa deer (*Cervus timorensis*) are present at a few locations in the wet tropics of northern Queensland. Concerns from members of the Far North Queensland Regional Organisation of Councils regarding the potential impacts of these animals resulted in a small collaborative project to identify control options that could be utilised to remove small populations from wet tropics environments, which pose significant challenges, particularly with regard to accessibility.

Methods
We test several monitoring techniques at sites within the wet tropics where feral deer have been reported to occur, including the use of activity transects, movement sensing remote cameras and community surveys. Once a suitable population is found, testing of appropriate control options commences. Trapping (e.g. Clover traps) is the primary technique utilised at this stage, with an initial focus on identifying a suitable bait to induce pre-feeding prior to trapping.

Progress in 2009–10
The trial is now complete. From this study we found that localised feral deer populations in the wet tropics bioregion can be adequately monitored using a combination of community surveys, activity transects and remote cameras installed at bait stations.

We also found that where feral deer readily feed at bait stations, small populations can be caught in Clover traps by trained staff. However, this proved challenging at locations where deer had an abundance of food and were not enticed by the bait offered. For example, near Bellenden Kerr the Clover trap was ineffective on a small population of rusa deer that had ample natural feed (pasture and wild guava) available. In contrast, at a location near Kuranda comprising much drier upland country, deer readily took to the corn and molasses presented at pre-feeding bait stations. In fact, a mature male was photographed feeding on the first night the bait was laid.

We captured a total of four animals; initially a hind with calf, followed by two mature stags on separate occasions. This demonstrates that multiple captures of small numbers of deer within one population can be achieved. However, the traps had to be moved several times to achieve these capture rates.

Funding in 2009–10
Queensland Government

Collaborators
- Cairns Regional Council
- Far North Queensland Regional Organisation of Councils

More information
For further information on this research project, visit the invasive plant and animal science pages on the Biosecurity Queensland website at www.biosecurity.qld.gov.au

Part 4 Research services

1. Pest management chemistry

Project dates
Ongoing

Project leader
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Other staff in 2009–10
Alyson Weier and Emily Strong

Objectives
- Provide advice on the use, impact and environmental toxicology of vertebrate pesticides and herbicides to support their effective and responsible use to manage pest animal and weed populations.
- Manufacture and monitor the quality of chemical pest control products used to manage pest animal and weed populations.
- Undertake chemical ecology research and analysis on pest populations.

Rationale
This project provides chemistry services as required to science, policy and operational activities within Biosecurity Queensland's Invasive Plants and Animals program.

Methods
In this project we provide chemical advice and support to pest management in Queensland and undertake toxicological and ecotoxicological investigations relating to the use of vertebrate pesticides. In May 2010, the laboratory relocated to the new Health and Food Sciences Precinct at Coopers Plains. Along with the laboratory and formulation facility at this site, we make use of facilities at other research stations and field sites.

We carry out tests using appropriate methodology dictated by the client and the research direction. The laboratory operates within a quality assurance framework and maintains analytical methods for a range of vertebrate pesticide and herbicide formulations.

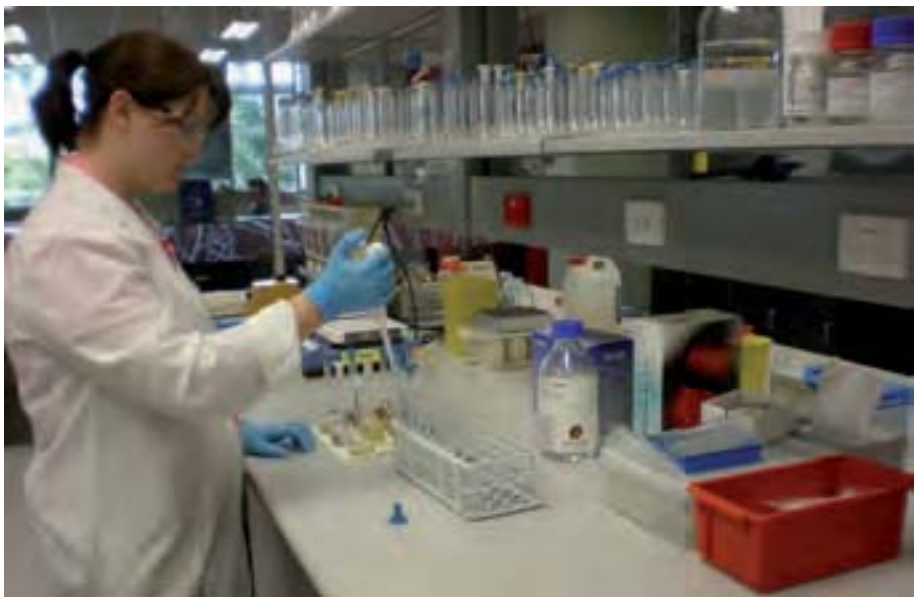

Photo 1. Experimentalist Alyson Weier preparing a sample for rodenticide analysis in the laboratory facilities at the Health and Food Sciences Precinct.

Progress in 2009–10
Ecotoxicology
The group completed laboratory determinations of 1080 (sodium fluoroacetate) residues in baits for input into the development of a model describing the degradation of 1080 baits in the environment.

We also provide residue data in wheat plant and grain for a rodenticide efficacy field trial using cholecalciferol (see project report '3.11 Effective and safe rodent management' on page 80). Work is still in progress, with 72 samples remaining to be analysed.

Forensic toxicology
Over the year, our laboratory performed 95 investigations relating to possible fluoroacetate poisoning, 43 relating to possible strychnine poisoning and 26 relating to possible anticoagulant poisoning. Most investigations related to domestic dogs and cats. However, there were some involving wildlife (macropods). Our laboratory also conducted total iodine analysis on a number of samples relating to animal health.

Formulation chemistry
During the year our formulation facility produced 300 L of 1080 concentrate for use in Queensland for the preparation of baiting solutions. This was supplemented with a further 60 L of 1080 pig bait solution and 60 L of 1080 dog bait solution.

The department maintains a strong testing program to ensure that sodium fluoroacetate baiting in Queensland meets agreed standards. Testing of post-preparation sodium fluoroacetate solutions and meat baits continued throughout the year. Additional testing of sodium fluoroacetate and rodenticide formulations was undertaken for industry.

Funding in 2009–10
- Land Protection Fund ($143 000)
- Queensland Government

2. Chemical registration: providing tools for invasive pest control

Project dates
Ongoing

Project leader
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Other staff in 2009–10
Joe Vitelli

Objective
Ensure that pesticides used for invasive plant and animal control are available and meet Australian regulatory requirements.

Rationale
Biosecurity Queensland currently holds a range of permits for the use of pesticides to control invasive plants and animals. The need for permits has increased as pesticide registrants focus primarily on crop protection with consequent greater economic returns, rather than environmental protection. This means that registered chemicals are less likely to be available for controlling invasive plant and animal species.

Methods
Applications to obtain registrations or permits for pesticide use follow a set of guidelines laid down by APVMA. The volume of information required varies depending on whether the chemical is already registered or allowed for another use, or is a new pesticide. Depending on the chemical and application, information may be required relating to:

- the chemistry and manufacture of the pesticide
- its toxicology, including its metabolism and kinetics
- likely crop and environmental residues
- occupational health and safety, associated both with its manufacture and its use
- its impact on the environment
- its efficacy and safety in use
- trade implications associated with the intended use.

While Biosecurity Queensland has primary responsibility for some pesticides, such as sodium fluoroacetate (1080), the project focuses on obtaining off-label permits for registered chemicals already in the market place. As a consequence, investigations are normally restricted to likely crop and environmental residues, impact on the environment and efficacy and safety in use relating to the use of a given pesticide in a new situation or for a new pest. Project staff work with other scientists to ensure data are available to address these issues and that any studies conducted for regulatory purposes meet APVMA requirements and guidelines.

Progress in 2009–10
During the past year the following minor use permits were renewed or obtained:

- permit (PER11541) for the use of registered glyphosate products containing 360 g L^{-1}, 540 g L^{-1}, 700 g L^{-1} active ingredient for the control of *Hymenachne* spp.
- permit (PER11561) for the control of kudzu (*Pueraria montana* var. *lobata* syn. *P. lobata*) using a variety of application methods for registered products containing 150 g L^{-1} imazapyr/150 g L^{-1} glyphosate, 600 g L^{-1} triclopyr, 300 g L^{-1} triclopyr/100 g L^{-1} picloram/8 g L^{-1} aminopyralid, 600 g L^{-1} metsulfuron methyl, 360 g L^{-1} glyphosate, 333 g L^{-1} fluroxypyr, 43 g L^{-1} picloram and 300 g L^{-1} clopyralid as the active ingredient
- permit (PER11772) for the use of registered pest control products containing 186 g L^{-1}, dichlorvos as the active ingredient for the monitoring of *Bactrocera* spp.
- permit (PER11833) for the control of Siam weed (*Chromolaena odorata*) using a variety of application methods for registered products containing 240 g L^{-1} triclopyr/120 g L^{-1} picloram, 300 g L^{-1} triclopyr/100 g L^{-1} picloram/8 g L^{-1} aminopyralid, 600 g L^{-1} metsulfuron methyl, 360 g L^{-1} glyphosate, 333 g L^{-1} fluroxypyr and 43 g L^{-1} picloram as the active ingredient
- permit (PER11669) for the use of registered products containing 625 g L^{-1} 2,4-D as the active ingredient for use as a targeted aerial application for the control of fireweed (*Senecio madagascariensis*)
- emergency permit (PER11670) for the control of water mimosa (*Neptunia plena* and *N. oleracea*) in aquatic situations using registered products containing 600 g L^{-1} metsulfuron methyl, 360 g L^{-1} glyphosate, 540 g L^{-1} glyphosate and 250 g L^{-1} amitrole/220 g L^{-1} ammonium thiocyanate as the active ingredient
- permit (PER11660) renewal for the use of 128 g L^{-1} fluazifop, 360 g L^{-1} glyphosate, 450 g L^{-1} glyphosate and 745 g L^{-1} flupropanate as the active ingredient for the control of all species of needle grasses (*Nassella* spp.)
- permit (PER11837) renewal for the use of registered products containing 745 g L^{-1} flupropanate as the active ingredient for the control of African lovegrass (*Eragrostis curvula*)
- permit (PER11920) renewal for the use of registered products containing 600 g L^{-1} metsulfuron methyl, 500 g L^{-1} 2,4-D amine and 300 g L^{-1} 2,4-D/75 g L^{-1} picloram as the active ingredient for the control of florestina (*Florestina tripteris*)
- permit (PER8500) renewal for the use of registered products containing 200 g L^{-1} imidacloprid as the active ingredient for the control of the lantana stem-sucking bug (*Aconophora compressa*).

Funding in 2009–10
- Queensland Government
- Land Protection Fund

Appendixes

1. Abbreviations

ACIAR
Australian Centre for International Agricultural Research

AFRS
Alan Fletcher Research Station

ANOVA
Analysis of variance

APVMA
Australian Pesticides and Veterinary Medicines Authority

AQIS
Australian Quarantine and Inspection Service

ARC-PPRI
Agricultural Research Council – Plant Protection Research Institute, South Africa

CABI
CAB International

C+C
Cholecalciferol and coumatetralyl

CRC
Cooperative Research Centre

CSIRO
Commonwealth Scientific and Industrial Research Organisation

CWTA
Centre for Wet Tropics Agriculture

DAFF
Department of Agriculture, Fisheries and Forestry, Australia

DEEDI
Department of Employment, Economic Development and Innovation, Queensland

DERM
Department of Environment and Resource Management, Queensland

DEWHA
Department of the Environment, Water, Heritage and the Arts, Australia

DDMRB
Darling Downs–Moreton Rabbit Board

DNA
Deoxyribonucleic acid

ELISA
Enzyme linked immuno sorbent assay

GPS
Global positioning system

MLA
Meat and Livestock Australia

NRETAS
Department of Natural Resources, Environment, The Arts and Sport, Northern Territory

NRMMC
Natural Resource Management Ministerial Council

NRMSC
Natural Resource Management Standing Committee

PAPP
Para-aminopropiophenone

PCR
Polymerase chain reaction

PhD
Doctor of Philosophy

QPWS
Queensland Parks and Wildlife Service

QUT
Queensland University of Technology

RHDV
Rabbit haemorrhagic disease virus

SE
Standard error

SPOT
Satellite pour l'observation de la terre

TWRC
Tropical Weeds Research Centre

UK
United Kingdom

UQ
The University of Queensland

VHF
Very high frequency

WONS
Weed(s) of National Significance

ZnP
Zinc phosphide

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3. Publications

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4. Presentations

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Campbell, S.D. 2009. *Using sap flow sensors to monitor woody weed activity*. Radio interview on ABC Rural. October.

5. Species

Scientific name	Common name
Acacia nilotica	prickly acacia
Acacia auriculiformis, *A. catechu*, *A. farnesiana*, *A. ferruginea*, *A. leucophloea* and *A. mellifera*	acacia
Aceria lantanae	lantana budmite
Aconophora compressa	lantana stem-sucking bug
Actinote anteas	mikania butterfly
Actinote thalia pyrrha	mikania butterfly
Agonosoma trilineatum	bellyache bush jewel bug
Alcidodes sedi	mother-of-millions weevil
Anacardium occidentale	cashew
Annona glabra	pond apple
Anomalococcus indicus	babul scale
Anredera cordifolia	Madeira vine
Apteromechus notatus	seed-feeding weevil
Astrebla squarrosa	bull Mitchell grass
Azadirachta indica	neem
Azolla sp.	azolla
Bactrocera spp.	fruit fly
Basella alba	Ceylon spinach
Bryophyllum delagoense	mother-of-millions
Bryophyllum spp.	mother-of-millions
Calotropis procera	calotrope (rubber bush)
Calycomyza lantanae	lantana leaf-mining fly
Canis lupus familiaris and *C. l. dingo*	wild dog
Carmenta ithacae	parthenium clear-wing moth
Carvalhotingis visenda	cat's claw creeper leaf-sucking tingid
Cascabella thevetia	Captain Cook tree (yellow oleander)
Cecropia peltata	Mexican bean tree
Cecropia palmata	trumpet tree
Cervus timorensis	rusa deer
Charidotis auroguttata	leaf-feeding tortoise beetle
Chromolaena odorata	chromolaena (Siam weed)
Clidemia hirta	clidemia (Koster's curse)
Clitoria ternatea	butterfly pea
Conotrachelus albocinereus	parthenium stem-galling weevil
Cylindrocopturus imbricatus	stem-boring weevil

Scientific name	Common name
Cylindropuntia rosea	Hudson pear
Cyperus aromaticus	navua sedge
Dactylopius tomentosus	cochineal insect
Dereodus denticollis	leaf-feeding weevil
Dereodus mastos	leaf-feeding weevil
Echeveria spp.	echeveria
Eichhornia crassipes	water hyacinth
Epiblema strenuana	parthenium stem-galling moth
Eragrostis curvula	African lovegrass
Euxestha abdominalis and *E.* aff. *panamena*	leaf- and shoot tip–mining larvae
Falconia intermedia	lantana mirid
Felis catus	feral cat
Florestina tripteris	florestina
Gmelina elliptica	badhara bush
Hylaeogena jureceki	leaf-mining buprestid beetle
Hymenachne amplexicaulis	hymenachne
Hypocosmia pyrochroma	cat's claw creeper leaf-tying moth
Irediparra gallinacea	comb-crested jacana
Jatropha curcas	physic nut
Jatropha gossypiifolia	bellyache bush
Kalanchoe blossfeldiana	kalanchoe
Lantana camara	lantana
Lemna sp.	duckweed
Leucaena leucocephala ssp. *glabrata*	leucaena
Limnocharis flava	limnocharis (yellow burhead)
Lippia alba	bushy lippia
Listronotus setosipennis	parthenium stem-boring weevil
Macfadyena unguis-cati	cat's claw creeper
Mangifera indica	mango
Melaleuca leucadendra	melaleuca
Melaleuca quinquenervia	melaleuca
Melaleuca viridiflora	melaleuca
Melomys spp.	rat
Miconia calvescens	miconia
Miconia nervosa	miconia
Miconia racemosa	miconia
Mikania micrantha	mikania vine (mile-a-minute)
Mimosa pigra	mimosa

Scientific name	Common name
Mus domesticus	house mouse
Nassella neesiana	Chilean needle grass
Nassella tenuissima	Mexican feather grass
Nassella trichotoma	serrated tussock
Neocrassana undata	sap-sucking psyllid bug
Neptunia plena and *N. oleracea*	water mimosa
Ophiomyia camarae	lantana herringbone leaf-mining fly
Ophiomyia lantanae	lantana seed-mining fly
Ormiscus/Eusphyrus sp.	tip borer
Oryctolagus cuniculus	rabbit
Osphilia tenuipes	mother-of-millions weevil
Pachycoris prob. *fabricii*	seed feeder
Parinari nonda	nonda plum
Parthenium hysterophorus	parthenium
Phakopsora jatrophicola	Jatropha rust fungus
Phycita sp.	leaf-webbing caterpillar
Phyla canescens	lippia
Piper nigrum	black pepper
Pistia stratiotes	water lettuce
Pityophthorus sp.	tip borer
Plectonycha correntina	Madeira vine leaf beetle
Prosopis pallida	mesquite
Prospodium tuberculatum	lantana rust
Puccinia lantanae	lantana rust
Puccinia xanthii var. *parthenii-hysterophorae*	parthenium summer rust
Puccinia spegazzinii	mikania rust
Pueraria montana var. *lobata* Syn. *P. lobata*	kudzu
Rattus spp.	rat
Ravenelia acacia-arabicae	prickly acacia galling rust
Ravenelia sp. nova	prickly acacia leaf rust
Salvinia molesta	salvinia
Scirtothrips aurantii	South African citrus thrips
Senecio madagascariensis	fireweed
Simsia sp.	bush sunflower
Smicronyx lutulentus	parthenium seed-feeding weevil
Spirodela sp.	duckweed
Sus scrofa	feral pig
Tecoma stans	yellow bells

Scientific name	Common name
Themeda quadrivalvis	grader grass
Uroplata girardi	lantana leaf-mining beetle
Verbena officinalis var. *africana*	verbena
Vulpes vulpes	red fox
Xanthium strumarium	rough cocklebur
Ziziphus mauritiana	chinee apple
Zygogramma bicolorata	parthenium leaf-feeding beetle

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