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

Technical highlights

Invasive plant and animal research 2008–09

Queensland Government

Technical highlights

Invasive plant and animal research 2008–09

PR09–4612

On 26 March 2009, the Department of Primary Industries and Fisheries was amalgamated with other government departments to form the Department of Employment, Economic Development and Innovation.

Cover photos (left to right): Researchers Alvaro Alves (left) and Acacio Guterres (right) investigating dieback of *Chromolaena odorata* in East Timor as a result of biological control. The bird-dispersed invasive vine *Passiflora suberosa*. Wild dog (*Canis lupus familiaris*) with satellite collar.

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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 key achievement this year has been the compilation of a management manual for bellyache bush. The manual incorporates key findings from many years of research into the ecology and control of this invasive weed. Numerous case studies are also included to share the experiences of land managers who have been controlling bellyache bush at various scales. The manual will be ready for distribution early in 2010.

We have established a comprehensive seed longevity trial at the Tropical Weeds Research Centre (TWRC) to quantify how long soil seed banks of several priority weeds persist in the absence of further seed input. Seeds of prickly acacia, mesquite, lantana, calotrope, parthenium, leucaena, yellow oleander, chinee apple and neem tree have been buried at several depths within two soil types and with two types of above-ground cover. Results will inform land managers on the required duration of control programs based on the time taken to exhaust soil seed reserves.

Development of effective herbicide recommendations for problematic weeds has continued. Most recently, researchers have been able to identify foliar herbicide options for the herbaceous annual weed, florestina, that not only provide high initial mortality but also residual control of seedling regrowth for several months.

Our biocontrol program has continued to focus on the identification of new biological control agents for prickly acacia and bellyache bush. While possibilities for bellyache bush appear limited, we have identified several potential agents for prickly acacia during initial surveys in India. These include two rust fungi and insects associated with stem galls, shoot-tip damage, defoliation and leaf-webbing. Surveys will continue over the coming year, and the most promising agents will be subjected to more detailed monitoring and host testing.

Landscape protection and restoration

Three major environmental weeds of Queensland continue to be targeted by our biocontrol program. Over 500 000 tingid bugs and a total of 50 000 leaf-tying moths have now been released against cat's claw creeper at 72 sites across Queensland and northern New South Wales. We have also imported a new potential biocontrol agent for host-specificity testing. Host-specificity testing of a leaf beetle targeting Madeira vine is nearing completion and testing of a new pathogen against lantana is underway in the United Kingdom (UK).

Research in support of Queensland's weed eradication programs has been a major focus of activity. An important new project developing effective control options and collecting basic ecological data that can inform eradication programs has commenced. Badhara bush, Mexican feather grass, water mimosa and Mexican bean tree were prioritised for the first year of research. For Siam weed, we are investigating the suitability of low volume, high concentration herbicide application though a 'gas gun' carried on a backpack. This technology could provide a safe, efficient option to control Siam weed in rugged terrain. We have also developed a model that predicts the duration and cost of eradication programs. This should prove useful when determining whether to attempt eradication and during reviews of eradication programs.

Our research into the characteristics of underground tuber banks in cat's claw creeper infestations has revealed that tubers were abundant in terms of density, yet small in size and with few connections between them. This work suggests that new recruitment of cat's claw creeper is primarily from seeds, not from vegetative propagation as previously thought. Future biological control efforts need to focus on introducing seed- and pod-feeding insects to reduce seed output.

Pest animal management

Tracking the movements of wild dogs in southern Queensland has shown dogs to be capable of extraordinarily long-distance dispersal (› 500 km in one month), and across hostile terrain including recently baited areas. Radio telemetry has also provided an interpretation of reported seasonal changes in dog activity. Dog activity is high during the autumn mating season when males in particular are spending a lot of time on roads. Following whelping and while rearing pups during winter and spring,

roads are rarely used by dogs and the activity index can falsely indicate the population has declined. These results have some important implications for management.

We are currently assessing the effectiveness of commercial harvesting of feral goats and pigs in controlling damage. For feral goats, initial analyses of historical survey data and harvest offtake figures suggest that harvesting has not reduced population numbers to levels where pest impact is acceptable. Despite annual harvests of over 100 000 animals and an increase in their value, Queensland's feral goat population has increased to over one million animals between 1984 and 2001. These results highlight that alternative control, including poison baiting or some form of support to the commercial harvesting industry, is warranted.

With increasing rabbit numbers across Australia, the benefits of warren ripping, particularly aimed at persistent 'source' populations that provide founders for expansion, are becoming clearer. At Bulloo Downs, the reduction in rabbit numbers to extremely low density following ripping in the drought refuge was maintained in 2008–09. We are now comparing ripped and unripped areas in south-east Queensland, with initial results promising similar beneficial outcomes. We are also supporting a national mapping project using RabbitScan, a web-based tool enabling communities across Australia to record rabbit abundance and impact using repeatable, quantitative measures. The resulting map will help better target and evaluate rabbit control programs at the regional, state and national levels.

Work on resistance to rabbit haemorrhagic disease virus (RHDV) has continued, with the surprising finding that the benign strain of rabbit calicivirus does not confer immunity to RHDV. This research is timely given the recent increase in rabbit numbers, revised high cost of rabbits to Australian agriculture (› $200 million per year) and current push to introduce a more effective strain of RHDV.

Research services

We have obtained or renewed permits for the use of eight pesticides and maintained the production of required amounts of 1080 solutions for use in Queensland's pest animal control programs. During 2008–09, our laboratory has also performed 150 toxicological investigations relating to the use of vertebrate pesticides, and added dicoumarin (a naturally occurring anticoagulant) to its profile of tests.

Business report

Following the Queensland state elections in March 2009, the Department of Primary Industries and Fisheries (DPI&F) and other state government departments amalgamated to form the Department of Employment, Economic Development and Innovation. DPI&F is now known as Queensland Primary Industries and Fisheries (QPIF).

Within this new structure, Invasive Plant and Animal Science remains part of Biosecurity Queensland.

As in previous years, our research program for 2008–09 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. In 2008–09, we also prepared a detailed research and development plan for approval by external stakeholders. This plan was discussed and subsequently endorsed by the Land Protection Council in October 2008.

A Class 1 plants prioritisation workshop was held at the Alan Fletcher Research Station (AFRS) in August 2008, in which criteria for prioritising research targets for the new project 'Class 1 weed control packages' were discussed and endorsed by senior Biosecurity Queensland staff. A wild dog research review was also held at AFRS in September 2008. Internal and external researchers and stakeholders reviewed existing knowledge, identified research gaps and set the direction for future wild dog research. A two-day workshop on the Siam Weed Eradication Program and Four Tropical Weeds Eradication Program in South Johnstone (April 2009) was attended by Biosecurity Queensland scientific staff and other stakeholders, and identified future research priorities as well as collaborative and funding opportunities.

In the financial year 2008–09, Invasive Plant and Animal Science received total funding of $7 million. Government base funds amounted to $4.5 million, the Land Protection Fund provided $1.8 million and funding from research and development contracts with external partners totalled $0.7 million (see the table overleaf).

The senior management and research team experienced some staff movements in 2008–09. Dr Tony Pople joined the team as Acting Principal Scientist and Professional Leader of the Robert Wicks Pest Animal Research Centre in September 2008, following the secondment of Dr Joe Scanlan to a Meat and Livestock Australia–funded project. Bob Parker has temporarily left his position as leader of the Research Services Program to act as Manager, Marine Biosecurity for the Invasive Plants and Animals Program, with Lesley Ruddle replacing him as Project Leader, Pest Management Chemistry and Karen Boundy joining us as the new Project Leader, Chemical Registration. Dr Wayne Vogler has progressed to a new Senior Weed Scientist position at the TWRC. Dr Tobias Bickel commenced duties as Project Leader, Aquatic Weed Management at AFRS in April 2009. In 2008–09, a total of 95 staff were engaged at our five research locations.

Collaboration and extension

Following the completion of the Cooperative Research Centre for Australian Weed Management (Weeds CRC) on 30 June 2008, the Australian Government announced the creation of a new Australian Weeds Research Centre and committed $15.3 million over four years. Three of our projects received a total of $120 000 in the first year of funding.

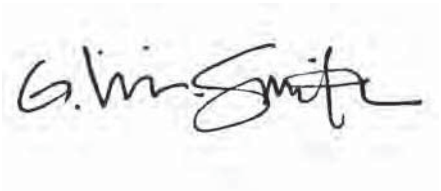
We continue to be a core participant in the Invasive Animals Cooperative Research Centre (Invasive Animals CRC), working closely with pest animal experts from across Australia on a range of joint projects (e.g. on rabbit resistance to RHDV and the development of a new bait for wild dogs, foxes and cats), and have also had some involvement with the Desert Knowledge Cooperative Research Centre (Desert Knowledge CRC).

We 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 include CSIRO, The University of Queensland (UQ), Queensland University of Technology (QUT), James Cook University, Australian Centre for International Agricultural Research (ACIAR), the Department of Environment and Resource Management (DERM)/Queensland Parks and Wildlife Service (QPWS) and the Agricultural Research Council—Plant Protection Research Institute (ARC-PPRI) in South Africa. Our new international partnerships with two Indian research groups—the Arid Forest Research Institute (AFRI) and the Institute of Forest Genetics and Tree Breeding (IFGTB)—and CAB International (CABI) Europe-UK are producing fruitful first results. 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 27 peer-reviewed articles in international (17) and national (10) journals, contributed 9 chapters to scientific books on weed management and ecology, and published 1 edited book. Our scientists had significant involvement in the planning of the Second Queensland Pest Animal Symposium held in Cairns in October 2008, and provided 12 presentations and several 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 4 and 5.

The *Technical highlights 2007–08 client feedback survey* sent out with last year's report was a great success, receiving almost 100 responses (approximately 20% of contacts on the *Technical highlights* mailing list). The survey showed that our clients are generally highly satisfied with *Technical highlights*; however, many would welcome further opportunities for interaction and more practical information to be included in project reports. As a first step, this year we have provided sources of further information and included contact details with each project report. As a result of the survey, more clients will receive this year's report electronically, a trend which we will continue to promote over the coming years. Finally, many valuable suggestions on how we can improve our service delivery were made. We have already delivered on some of the issues by improving our web service. The invasive plant and animal science web pages on the QPIF website (www.dpi.qld.gov.au) have been restructured to reflect our four statewide program areas and include a dedicated page for each current research project. Improved internet presentation of our scientific publications through the fully searchable QPIF eResearch Archive (on the QPIF website) is currently in progress.

I am pleased to present *Technical highlights: Invasive plant and animal research 2008–09* to our clients, as well as to our collaborators and colleagues. If you have any comments or require further information, please contact me (gabrielle.viviansmith@deedi.qld.gov.au) or one of our research group's professional leaders.



Dr Gabrielle Vivian-Smith
Principal Scientist
Invasive Plant and Animal Science
Biosecurity Queensland
Department of Employment, Economic Development and Innovation

External funding 2008-09

Research and development contracts

Project	Funds ($)	Funding body
Understanding grader grass ecology for improved management	19 000	NQ Dry Tropics; Northern Gulf Resource Management Group and Southern Gulf Catchments
Understanding grader grass ecology for improved management	15 000	Northern Gulf Resource Management Group
National bellyache bush best practice manual	60 000	DAFF
Biological control of prickly acacia	94 000	Meat and Livestock Australia
Biological control of lantana	79 000	Defeating the Weed Menace
Biological control of mikania vine in PNG and Fiji	69 000	ACIAR
Biological control of two weeds in East Timor	7 000	ACIAR
Weed eradication feasibility and program evaluation	26 000	CRC for Australian Weed Management
Weed eradication feasibility and program evaluation	25 000	DAFF
Ecology of Wet Tropics weeds	30 000	National Four Tropical Weeds Eradication Program
Ecology of bird dispersed weeds	19 000	CRC for Australian Weed Management
Water weed management	24 000	DAFF
Best practice baiting—dispersal and seasonal movement of wild dogs	11 000 1 000	Desert Channels Queensland Bureau of Rural Sciences
Development of a cyanide bait for monitoring feral pigs and foxes	18 000	Wildlife and Exotic Diseases Preparedness Program
Assessing the role of feral pig harvesting	174 000	QMDC
Feral pig impacts on freshwater ecosystems	28 000	DEWHA
Modelling options for management of feral camels in central Australia	31 000	Desert Knowledge CRC
Testing feral deer control in the Far North Queensland Wet Tropics	3 000	Wet Tropics Management Authority, Terrain Natural Resource Management
Total	**733 000**	

Land Protection Fund

Project/research area	Funds ($)
Understanding grader grass ecology for improved management	83 000
Integrated management of bellyache bush in northern Queensland	34 000
Biological control of bellyache bush	29 000
Dry tropics weed research	131 000
Seed dynamics	177 000
Biological control of prickly acacia	30 000
Biological control of mother-of-millions	79 000
Biological control of cat's claw creeper	168 000
Biological control of Madeira vine	95 000
Biological control of lantana	127 000
Weed eradication feasibility and program evaluation	27 000
Wet Tropics weed research	31 000
Class 1 weed control packages	57 000
Environmental weed research (invasive woody vine ecology, population ecology of lantana)	20 000
Water weed management and control	88 000
Pest animal research operations	22 000
Wild dog research	211 000
Dry tropics feral pig research	93 000
Rabbit research	166 000
Pest management chemistry and chemical registration	121 000
Total	**1 789 000**

Part 1 Integrated weed management

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

Project dates

July 2006 – June 2014

Project leader

Wayne Vogler, Tropical Weeds Research Centre
Tel: (07) 4761 5707
Email: wayne.vogler@deedi.qld.gov.au

Other staff

Will Green, Ashley Owen, Rebecca Stacey and Troy Johnson

Objectives

- Understand responses of grader grass to fire frequency and timing, effect of fire on seed production and viability, 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 understand 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–infested native woodland in northern Queensland.

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, recover these bags at various intervals and test seed viability by germination and use of standard tetrazolium testing procedures.

Effect of fire, physical biomass removal and seed head removal

In this trial we examine the effect of fire, physical biomass removal and grader grass seed head removal on grader grass soil seed banks, seedling recruitment and pasture composition. This is a replicated plot trial where each of the treatments (fire during dry season, fire at start of wet season, seed head removal, biomass removal during late dry season) is imposed on an annual basis. We impose combinations of treatments as the results of initial treatments are obtained. This includes monitoring changes in pasture species and biomass composition (using the Botanal methodology), soil seed banks of grader grass, seasonal growth cycle of grader grass, grader grass plant survival and seed production, and soil fertility.

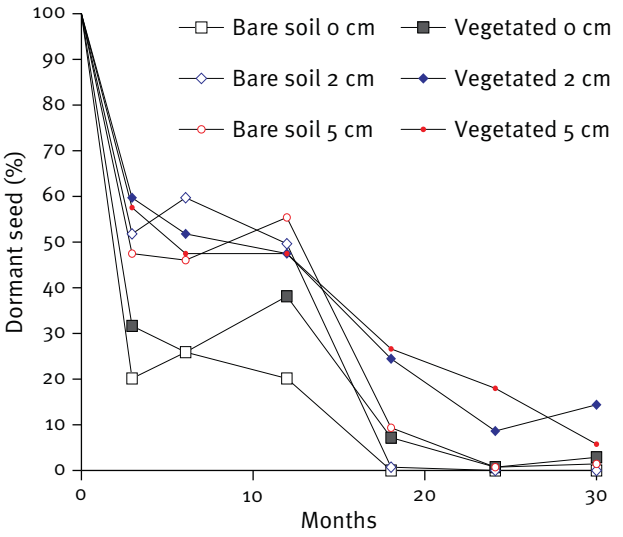


Figure 1. Grader grass dormant seed decline in artificial seed banks buried in November 2006 in bare and vegetated plots at 0 cm, 2 cm and 5 cm depths.

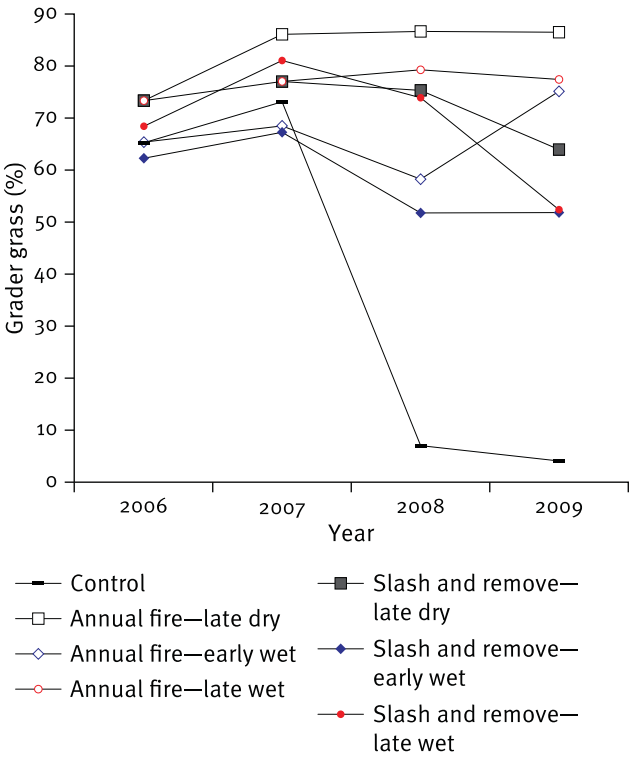


Figure 2. Grader grass biomass in fire, slash and remove, and control treatments at Lynwater Station.

Progress

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 three wet seasons, surface dormant seed (regardless of cover) and buried dormant seed (without cover at 2 cm and 5 cm depths) had declined to almost zero, while dormant seed in other treatments remained between 5% and 15%. This indicates that vegetative cover and burial depths below 2 cm assist in maintaining seed viability for longer periods.

Following the 2007–08 wet season the natural soil seed bank declined to 3% of the original viable seed bank. This confirms that when seed input is stopped and seedlings are controlled the natural soil seed bank declines to near zero relatively quickly. The results of the natural seed bank decline experiment are comparable with that of the buried seed bank decline experiments and indicate that using artificial seed banks is a valid method for estimating seed bank persistence.

Effect of fire, physical biomass removal and seed head removal

Grader grass biomass was generally maintained in fire and slash and remove treatments applied at any time of year. In contrast, where disturbance was minimal (such as in the control, herbicide and landholder-managed treatments), grader grass biomass continued to decline following the third year of treatment application (figures 2 and 3). When slashing occurred prior to seed set, biomass increased in the third year even though seed production was reduced to almost zero. These results continue to confirm that grader grass invasion and dominance is inherently related to the level of disturbance within a pasture system, whether by overgrazing, fire, slashing or intensive soil disturbance such as along roads or fire breaks. It also suggests that managing to minimise disturbance will be a critical factor in reducing the presence and impact of this invasive grass.

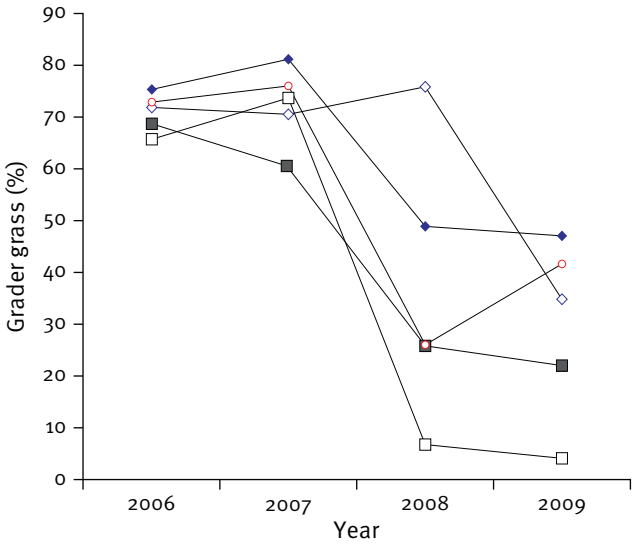


Figure 3. Grader grass biomass in herbicide, slashing pre–seed set, landholder-managed and control treatments at Lynwater Station.

Funding in 2008–09

Queensland Government

Northern Gulf Resource Management Group ($15 000)

NQ Dry Tropics, Northern Gulf Resource Management Group and Southern Gulf Catchments ($19 000)

Collaborators

DERM/QPWS, Undara National Park

DERM, Fire Unit

NQ Dry Tropics

Northern Gulf Resource Management Group

Southern Gulf Catchments

Landholders

More information

Key publications

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.

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 QPIF website at www.dpi.qld.gov.au

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

Project dates

July 2000 – June 2010

Project leader

Faiz Bebawi, Tropical Weeds Research Centre
Tel: (07) 4761 5716
Email: faiz.bebawi@deedi.qld.gov.au

Other staff

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 fire, slashing, stick-raking and chemical treatments for controlling bellyache bush.

Weed ecology

Seed bank (initiated in December 2000): We examine the seed bank of bellyache bush after the complete removal of infestations at two sites (heavy clay and rocky habitat).

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

Integrated weed control

Field trials were completed in June 2006. For final results see *Technical highlights 2005–06*. A scientific publication on the results is nearing completion.

Weed ecology

Seed bank: The experiment is complete. For final results see *Technical highlights 2006–07*.

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 2%) 96 months after burial, particularly at the 0 cm on mulched ground, 5 cm and 20 cm depths. As there is still a small quantity of viable seed remaining, another lot of samples will be tested in 2010.

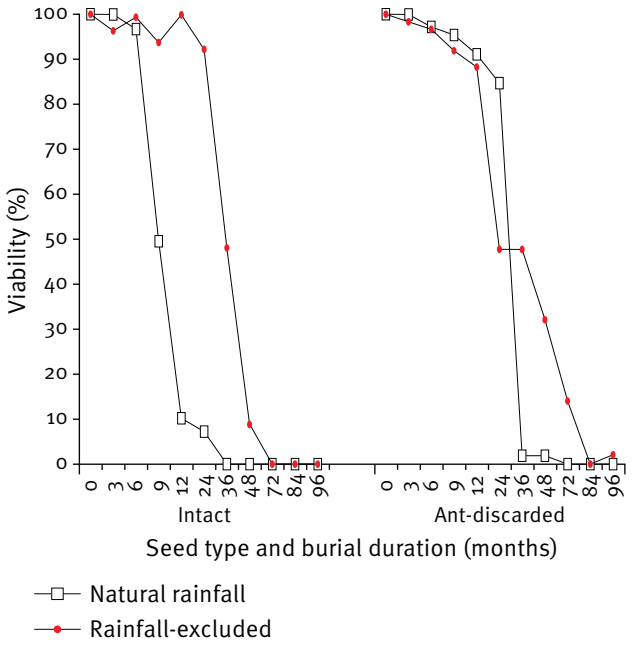


Figure 1. Viability of intact and ant-discarded seeds over 96 months in natural and rainfall-excluded sites, averaged over all burial depths.

Pasture management research: Under the simulated grazing conditions of this trial, pasture yield has been 36% and 18% greater in high and medium grazing plots compared with those that have been subjected to low grazing (Figure 2), irrespective of the density of bellyache bush present.

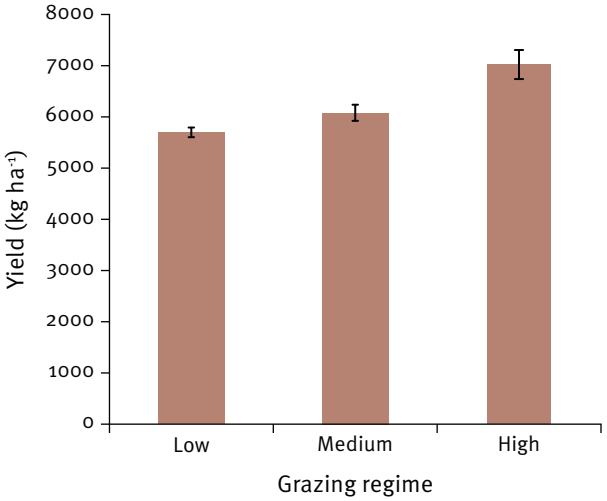


Figure 2. Pasture yield as affected by different simulated grazing regimes. (Vertical bars indicate the standard error (SE) of the means.)

After seven years, minimal mortality (4%) has occurred in areas devoid of pasture (i.e. pasture removed). In contrast, mortality has ranged from 67% in the no grazing plots to 73% under high grazing. The trial is ongoing.

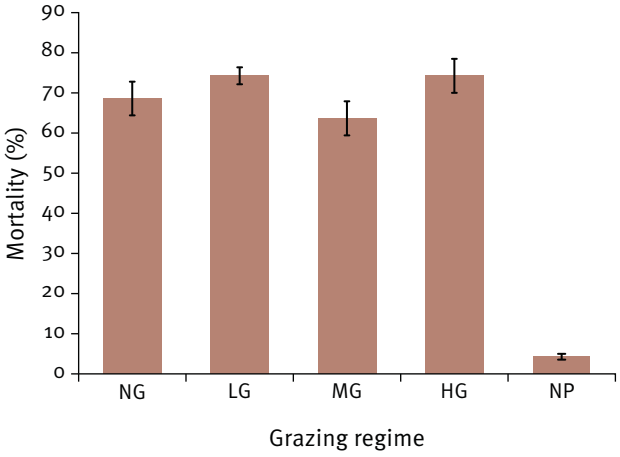


Figure 3. Mortality of bellyache bush plants in areas devoid of pasture (NP) and subjected to no grazing (NG), low grazing (LG), medium grazing (MG) and high grazing (HG) regimes, seven years after treatment. (Vertical bars indicate the SE of the means.)

Funding in 2008–09

Land Protection Fund

Queensland Government

Collaborators

Ralph Woodard (Branmore Station)

More information

Key publications

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.

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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 QPIF website at www.dpi.qld.gov.au

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

Project dates

February 2009 – December 2009

Project leader

Shane Campbell, Tropical Weeds Research Centre
Tel: (07) 4761 5704
Email: shane.campbell@deedi.qld.gov.au

Other staff

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 Weeds CRC. 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

A full draft of the manual has been compiled and feedback is being sought from stakeholders. The manual wil be submitted for professional editing in October 2009, and copies of the publication will be ready for distribution by early 2010.

Funding in 2008–09

DAFF ($60 000)

Collaborators

CSIRO

Department of Agriculture and Food, Western Australia

Natural Resources, Environment, The Arts and Sport, Northern Territory

More information

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

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

Project dates

July 2007 – June 2012

Project leaders

Faiz Bebawi, Tropical Weeds Research Centre
Tel: (07) 4761 5716
Email: faiz.bebawi@deedi.qld.gov.au

John McKenzie, Tropical Weeds Research Centre
Tel: (07) 4761 5718
Email: john.mckenzie@deedi.qld.gov.au

Other staff

Chris Crowley, Dannielle Brazier and Shane Campbell

Objectives

- Better understand the ecology of Captain Cook tree and the implications for timing and effectiveness of control strategies.
- Evaluate the effectiveness of chemical control techniques including basal bark, cut stump, foliar application and stem injection on Captain Cook tree.

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 and developing effective control options is essential to reducing its economic, environmental and social impacts.

Methods

There are two areas of research associated with this project—weed ecology and control of Captain Cook tree.

Weed ecology

There are five experiments.

Experiment 1 is determining 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. We are currently repeating this study to see if similar trends occur over several years.

Experiment 2 is determining 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-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 is determining 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 is monitoring seed production and seed predation of peach-flowering plants growing under natural conditions at Will Creek, Mingela. We establish six permanent 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 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-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 11.4–52.5 ˚C during the day and 6.1–40 ˚C during the night is allocated to sub-experiment 5a and a constant temperature range of 13.6–49.2 ˚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.

Weed control

We conduct four experiments at Will Creek, Mingela, to determine which herbicides and rates are most effective in controlling Captain Cook tree using basal bark, foliar, cut stump or stem injection techniques. Experiments for each technique are completely randomised, incorporating three replications. We test the efficacy of herbicides on three size classes (‹ 20 mm, 21–50 mm and › 51 mm). Each size class comprises 10 plants and we record reproductive status prior to treatment. We use an arbitrary rating system to assess treatment damage.

Progress

Weed ecology

Experiment 1: Preliminary results show that both peach- and yellow-flowering plants have the capacity to germinate all year round, but tend to prefer spring conditions. Maximum germination of peach-flowering (90%) and yellow-flowering (87%) plants occurred in September and October, respectively. The September and October ambient temperatures ranged between 13.7 ˚C and 30.6 ˚C and 17.3 ˚C and 33.5 ˚C, respectively. Hot summer conditions in north Queensland appear less favourable for germination, with ‹ 30% germination recorded in this study during December and January (Figure 1).

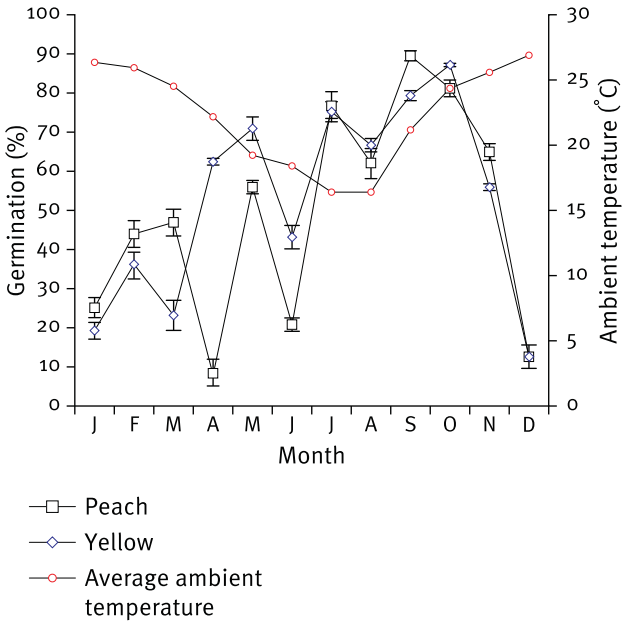

Figure 1. Germination of peach- and yellow-flowering plants and prevailing average ambient temperatures. (Vertical bars indicate the SE of the means.)

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. Shading delayed reproduction for both flowering types, but more so for the peach-flowering plants. Some peach- and yellow-flowering plants growing at the two highest densities under shade have not yet reached reproductive maturity (Figure 2).

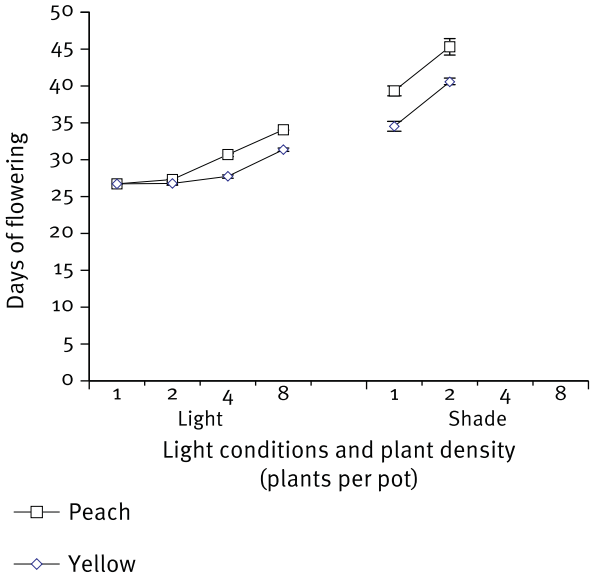

Figure 2. Days to flowering of peach- and yellow-flowering plants growing at different plant densities and under natural light or shaded conditions. (Vertical bars indicate the SE of the means.)

Other key findings to date include the following:

- At flowering, peach-flowering plants were shorter than yellow-flowering plants when grown under natural light conditions. Both types were shorter under natural light than in shade conditions.
- At flowering, basal diameter of peach-flowering plants was usually greater compared to yellow-flowering plants. Basal diameter of both types declined with increases in plant density.
- Both flowering types produced more pods when grown in natural light compared to shade conditions. However, yellow-flowering plants were more prolific in natural light compared with peach-flowering plants, whereas no marked differences were detected in pod production under shade conditions. Pod production of both types was negatively correlated with plant density (Figure 3).

The experiment is ongoing.

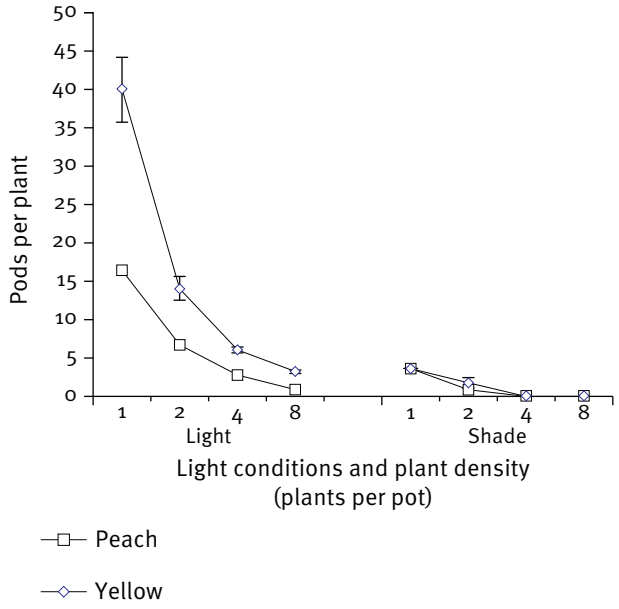

Figure 3. Pod production of peach- and yellow-flowering as affected by plant densities and light conditions. (Vertical bars indicate the SE of the means.)

Experiment 3: This experiment was initiated in January 2008. Fourteen months after germination, plant height was five-fold greater than the initial height under light, compared with a two-fold increase under shade. Similarly, basal diameter was four-fold greater under natural light compared with two-fold greater under shade. These results contrast with those in the pot experiment (Experiment 2) and appear reflective of the other factors in force in the field, such as competition for nutrients and soil moisture. Seedling survival was significantly greater under light conditions (82%) compared with shade conditions (65%) (Figure 4). The experiment is ongoing.

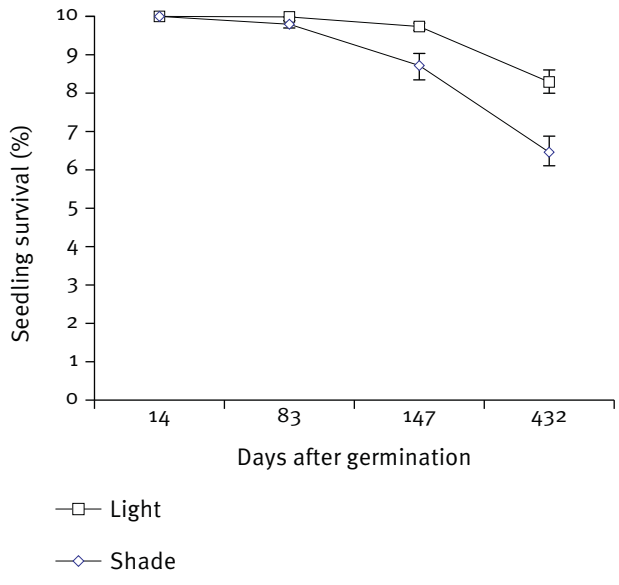

Figure 4. Seedling survival of peach-flowering plants as affected by light conditions at Mingela. (Vertical bars indicate the SE of the means.)

Experiment 4: This experiment was initiated in January 2008. The population density of peach-flowering plants at Will Creek was in the range 63 000 ± 4700 plants ha^{-1}. Seed production occurred all year but was highest in autumn (April) and throughout winter (Figure 5). Similarly, seed predation by wildlife (including parrots) occurred all year and was positively correlated with seed production (R^2 = 0.96) (Figure 5). Seed predation peaked in June (83%). This amounted to a consumption of 1.2 kg seeds ha^{-1}, potentially reducing dispersal. Such predation appears to be due to the high fatty acid content of the seeds (e.g. total fat 60.7%, palmitic acid 13.5%, stearic acid 4.4%, oleic acid 26.9%, linoleic acid 13.3% and arachidic acid 0.8%).

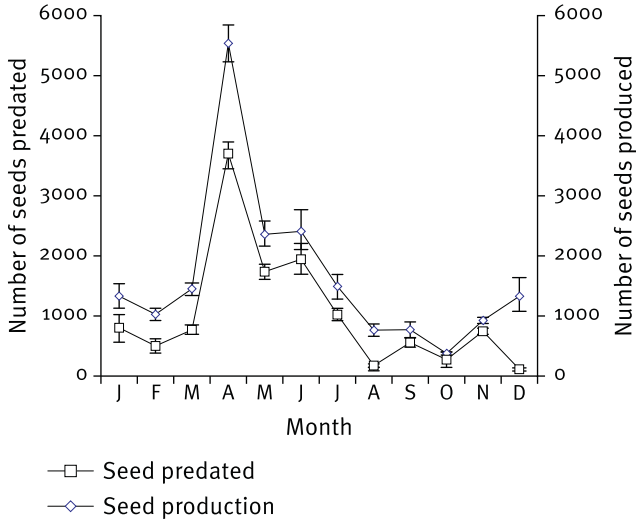

Figure 5. Seed production and seed predation of peach-flowering plants at Mingela. (Vertical bars indicate the SE of the means.)

Experiment 5: We detected significant interactions ($p < 0.013$) in germination response between the two flowering types in the alternating temperature regimes. The peach-flowering plants favoured a temperature range of 19.4/25.1–30.1/37.7 ˚C, compared with 19.4/25.1–33.3/42.1 ˚C for the yellow-flowering type. Nil germination occurred at alternating temperatures of > 36.8/47.3 ˚C and < 11.5/16.5 ˚C.

In the constant temperature experiment (initiated in June 2009), peak germination occurred at 27.3 ˚C for both flowering types. However, nil germination occurred at constant temperatures of > 44.4 ˚C and < 17 ˚C for peach-flowering plants, in contrast to > 39.6 ˚C and < 17 ˚C for yellow-flowering plants. Results of both experiments suggest that the germination temperature tolerance range (11–47 ˚C) of both varieties is wide, but temperatures of < 11 ˚C or > 47 ˚C may be detrimental to germination.

Weed control

Results for the basal bark spraying, cut stump treatment, foliar spraying and stem injection experiments are shown in tables 1 and 2.

Table 1. Mortality of Captain Cook tree, irrespective of size class, treated by basal bark and cut stump methods using various herbicides and rates at Mingela. (Values followed by the same superscript letter within the same treatment are not significantly different, $p < 0.05$. D = Diesel; W = Water + wetter.)

Treatment	Active ingredient	Rate	Mortality (%)
Basal bark	triclopyr (240 g L^{-1}) + picloram (120 g L^{-1})	1:30D	63.3^{b}
Basal bark	triclopyr (240 g L^{-1}) + picloram (120 g L^{-1})	1:60D	47.8^{c}
Basal bark	fluroxypyr (200 g L^{-1})	1:66.6D	53.3^{bc}
Basal bark	fluroxypyr (200 g L^{-1})	1:33.3D	98.9^{a}
Basal bark	neat diesel	D	0^{d}
Basal bark	control	–	0^{d}
Cut stump	triclopyr (240 g L^{-1}) + picloram (120 g L^{-1})	1:30D	65.6^{e}
Cut stump	triclopyr (240 g L^{-1}) + picloram (120 g L^{-1})	1:60D	75.6^{de}
Cut stump	fluroxypyr (200 g L^{-1})	1:66.6D	96.7^{ab}
Cut stump	fluroxypyr (200 g L^{-1})	1:33.3D	100^{a}
Cut stump	picloram (43 g kg^{-1})	straight	91.1^{abcd}
Cut stump	metsulfuron methyl (600 g kg^{-1})	1 g:10W	2.2^{g}
Cut stump	metsulfuron methyl (600 g kg^{-1})	1 g:1W	23.3^{f}
Cut stump	triclopyr (200 g L^{-1}) + picloram (100 g L^{-1})	1:20W	92.2^{abc}
Cut stump	triclopyr (200 g L^{-1}) + picloram (100 g L^{-1})	1:40W	77.8^{cde}
Cut stump	2,4-D (625 g L^{-1})	1:5W	96.7^{ab}
Cut stump	2,4-D (625 g L^{-1})	1:10W	83.3^{bcd}
Cut stump	glyphosate (360 g L^{-1})	1:2W	91.1^{abcd}
Cut stump	glyphosate (360 g L^{-1})	1:4W	93.3^{abc}
Cut stump	2,4-D (300 g L^{-1}) + picloram (75 g L^{-1})	1:14.8W	95.6^{ab}
Cut stump	2,4-D (300 g L^{-1}) + picloram (75 g L^{-1})	1:12.8W	75.6^{de}
Cut stump	neat diesel	D	4.4^{g}
Cut stump	control	W	3.3^{g}

Table 2. Mortality of Captain Cook tree, irrespective of size class, treated by foliar spraying and stem injection methods using various herbicides and rates at Mingela. (Values followed by the same superscript letter within the same treatment are not significantly different, $p < 0.05$. W = Water + wetter.)

Treatment	Active ingredient	Rate	Mortality (%)
Foliar	triclopyr (300 g L^{-1}) + picloram (100 g L^{-1})	1:150W	32.2^{bc}
Foliar	triclopyr (300 g L^{-1}) + picloram (100 g L^{-1})	1:300W	28.9^{bcd}
Foliar	triclopyr (300 g L^{-1}) + picloram (100 g L^{-1}) + aminopyralid (8 g L^{-1})	1:150W	44.4^{b}
Foliar	triclopyr (300 g L^{-1}) + picloram (100 g L^{-1}) + aminopyralid (8 g L^{-1})	1:300W	40^{bc}
Foliar	metsulfuron methyl (600 g kg^{-1})	10 g:100W	11.1^{de}
Foliar	metsulfuron methyl (600 g kg^{-1})	20 g:100W	23.3^{cd}
Foliar	2,4-D (300 g L^{-1}) + picloram (75 g L^{-1})	1:112W	30^{bcd}
Foliar	2,4-D (300 g L^{-1}) + picloram (75 g L^{-1})	1:225W	24.4^{bcd}
Foliar	fluroxypyr (200 g L^{-1})	1:200W	86.7^{a}
Foliar	fluroxypyr (200 g L^{-1})	1:100W	96.7^{a}
Foliar	control	W	2.2^{e}
Stem injection	triclopyr (200 g L^{-1}) + picloram (100 g L^{-1})	1:4W	100^{a}
Stem injection	triclopyr (200 g L^{-1}) + picloram (100 g L^{-1})	1:8W	80.66^{ab}
Stem injection	hexazinone (250 g L^{-1})	1:2W	46.58^{c}
Stem injection	hexazinone (250 g L^{-1})	1:4W	47.78^{c}
Stem injection	glyphosate (360 g L^{-1})	1:0W	98.25^{a}
Stem injection	glyphosate (360 g L^{-1})	1:1W	93.07^{a}
Stem injection	2,4-D (300 g L^{-1}) + picloram (75 g L^{-1})	1:2.75W	94.74^{a}
Stem injection	2,4-D (300 g L^{-1}) + picloram (75 g L^{-1})	1:5.75W	57.18^{bc}
Stem injection	imazapyr (250 g L^{-1})	1:4W	90^{a}
Stem injection	metsulfuron methyl (600 g kg^{-1})	1 g L^{-1}	33.33^{cd}
Stem injection	metsulfuron methyl (600 g kg^{-1})	0.5 g L^{-1}	5^{de}
Stem injection	control	W	0^{e}

Funding in 2008–09

Land Protection Fund

Queensland Government

Collaborators

John Ramsey, Landholder (Meadow Vale Cattle Station, Mingela)

Bob J. Mayer, Senior Biometrician (QPIF, Oonoonba)

Carole Wright, Biometrician (QPIF, Oonoonba)

More information

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

5. Seed dynamics

Project dates

August 2007 – ongoing

Project leader

Faiz Bebawi, Tropical Weeds Research Centre
Tel: (07) 4761 5716
Email: faiz.bebawi@deedi.qld.gov.au

Other staff

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 is currently limited.
- Develop germination and viability testing techniques for the above-mentioned weeds if none are 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 for 10 priority species in central and northern Queensland.

Methods

We establish a long-term experiment on the grounds of TWRC designed to determine the longevity of up to 12 species under different burial depths, soil types and levels of grass cover.

A 2 × 2 × 4 × 10 factorial design is incorporated, 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.

Progress

We have buried seeds of seven Class 2 or Class 3 declared weeds , including 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 two other species—neem (*Azadirachta indica*) and leucaena (*Leucaena leucocephala* ssp. *glabrata*). Preliminary results will be presented in coming years once seed lots start being retrieved at the predetermined intervals and subjected to germination and viability tests.

Photo 1. Dr Bruce Wilson (General Manager, Invasive Plants and Animals, Biosecurity Queensland) and Dr Faiz Bebawi burying seed capsules on site at TWRC, Charters Towers.

Funding in 2008–09

Queensland Government

Land Protection Fund

Collaborators

Bob J. Mayer, Senior Biometrician (QPIF, Oonoonba)

Carole Wright, Biometrician (QPIF, Oonoonba)

More information

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

6. Florestina (*Florestina tripteris*) herbicide trial

Project dates

March 2007 – December 2009

Project leader

John McKenzie, Tropical Weeds Research Centre
Tel: (07) 4761 5718
Email: john.mckenzie@deedi.qld.gov.au

Other staff

Dannielle Brazier, Ashley Owen, 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 the Australian Pesticides and Veterinary Medicines Authority (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 effect of a range of herbicides, we undertake a randomised complete block experiment with each treatment replicated four times. The field site is located at Kyneton, a mixed grazing enterprise 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.

Photo 1. Adult florestina plant.

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 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

Chemical screening trial

The chemical screening trial was conducted between September 2007 and January 2008. Metsulfuron methyl; triclopyr + picloram; 2,4-D + picloram; 2,4-D; clopyralid; aminopyralid + fluroxypyr; and picloram products provided high mortality and some residual control for florestina.

Rate response trials

The first rate response trial was conducted between January and October 2008. Chemicals containing the active ingredients metsulfuron methyl, aminopyralid and picloram resulted in good mortalities and residual effects (Table 1).

The second rate response trial commenced in March 2009. Mortality in this trial was high (Table 2). We are currently waiting for rain to be able to assess any residual effects.

Funding in 2008–09

Land Protection Fund

Queensland Government

Collaborators

Brett Carlson (Desert Channels Queensland)

More information

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

Table 1. Treatments, florestina mortality and seedling recruitment for the first rate response trial. (All treatments include Uptake as the wetting agent. Values followed by the same superscript letter within a column are not significantly different, $p < 0.05$. AI = Active ingredient; DAT = Days after treatment.)

Mix	Active ingredient	AI (g L^{-1} or kg^{-1} of product)	Product ha^{-1}	AI (g ha^{-1})	Mortality 197 DAT (%)	Recruitment (seedlings m^{-1})
1	metsulfuron methyl	600	60 g	36	100^{a}	0^{j}
2	metsulfuron methyl	600	7 g	4.2	86^{abcd}	17.5^{abcd}
3	metsulfuron methyl	600	14 g	8.4	92^{abc}	9.2^{cdefg}
4	triclopyr + picloram	300 + 100	0.75 L	225 + 75	97^{ef}	5.5^{cdef}
5	triclopyr + picloram	300 + 100	1.5 L	450 + 150	98^{a}	0.2^{ij}
6	triclopyr + picloram	300 + 100	3 L	900 + 300	100^{a}	0^{j}
7	2,4-D + picloram	300 + 75	0.75 L	225 + 56.2	82^{abcd}	4.9^{cdefg}
8	2,4-D + picloram	300 + 75	1.5 L	450 + 112	95^{ab}	19.9^{efghi}
9	2,4-D + picloram	300 + 75	3 L	900 + 225	100^{a}	0^{j}
10	2,4- D	625	1.44 L	900	68^{cde}	32^{abcde}
11	2,4- D	625	0.72 L	450	60^{de}	46.4^{abc}
12	2,4- D	625	0.36 L	225	64^{ef}	183^{a}
13	clopyralid	300	0.6 L	180	81^{abc}	30.4^{bcdef}
14	clopyralid	300	0.9 L	270	93^{ab}	5.5^{ghij}
15	clopyralid	300	1.2 L	360	89^{abc}	0.2^{hij}
16	fluroxypyr + aminopyralid	140 + 10	4 L	560 + 40	99^{abc}	7.5^{defgh}
17	fluroxypyr + aminopyralid	140 + 10	2 L	280 + 20	95^{ab}	9^{fghi}
18	fluroxypyr + aminopyralid	140 + 10	1 L	140 +10	82^{abcd}	7.6^{bcdef}
19	picloram	20	3750 g	75	84^{bcde}	6.4^{cdefg}
20	picloram	20	7500 g	150	90^{abcd}	31.6^{ab}
21	picloram	20	15 000 g	300	94^{ab}	10.7^{bcdef}
22	water (control)				29^{f}	201.2^{a}

Table 2. Treatments, florestina mortality and seedling recruitment for the second rate response trial. (All treatments include Uptake as the wetting agent. Values followed by the same superscript letter are not significantly different, p < 0.05. AI = Active ingredient.)

Mix	Active ingredient	AI (g L^{-1} or kg^{-1} of product)	Product ha^{-1}	AI (g ha^{-1})	Mortality (%)
1	metsulfuron methyl	600	20 g	12	95^{bc}
2	metsulfuron methyl	600	30 g	18	99^{c}
3	triclopyr + picloram	300 +100	1.7 L	510 + 170	89^{b}
4	triclopyr + picloram	300 + 100	2.3 L	690 + 230	94^{bc}
5	2,4-D + picloram	300 + 75	2.25 L	675 + 169	94^{bc}
6	2,4-D + picloram	300 + 75	3 L	900 + 225	100^{c}
7	water				40^{a}

Photo 2. Second rate response trial (a) before treatment and (b) after treatment with metsulfuron methyl at 30 g ha^{-1}.

7. Evaluating the effectiveness of the EZ-Ject herbicide lance

Project dates

December 2007 – December 2009

Project leader

Joseph Vitelli, Alan Fletcher Research Station
Tel: (07) 3375 0751
Email: joseph.vitelli@deedi.qld.gov.au

Other staff

Barbara Madigan

Objective

Evaluate the effectiveness of the EZ-Ject herbicide lance as a control method for woody weeds in Queensland using both glyphosate- and imazypyr-filled shells.

Rationale

The EZ-Ject herbicide lance is a relatively new technique for the control of woody plants by stem injection. The stainless steel lance has gripping teeth at the end and a spring-loaded assembly that injects .22 brass shells filled with water soluble herbicide into the cambium layer of woody plants. No mixing of, or contact with, the herbicide is required by the operator. The longer version of the lance (1.5 m) holds up to 100 shells in each of four separate shell chambers. The shells are implanted at a downward angle evenly around the circumference of the base of the plant. Two herbicides (glyphosate and imazypyr) are registered for use with the lance in the United States and Canada. Plants may be injected at any time of the year and may be standing in water or wetlands, though the injection site should be above the water level.

Photo 1. Experimentalist Barbara Madigan trialling the EZ-Ject herbicide lance.

To trial this control method, three woody weeds were chosen, each from a different family and each infesting a different area of Queensland. Yellow oleander (*Cascabella thevetia*), family Apocynaceae, is a Class 3 declared plant that is highly toxic and invades native vegetation. Velvety tree pear (*Opuntia tomentosa*), family Cactaceae, is a Class 2 declared plant found predominantly in the brigalow belt of Queensland. Pond apple (*Annona glabra*), family Annonaceae, is a Weed of National Significance (WONS) and a Class 2 declared plant. It can grow in flooded areas of fresh, brackish or salt water, forming dense thickets capable of replacing existing ecosystems.

If effective and subsequently registered for use in Queensland, this tool would help the operator avoid direct contact with both herbicide and any thorns or spines on the plant. The technique would be particularly useful in wetlands and other sensitive environments, allowing treatment of individual plants without affecting surrounding native vegetation or contaminating waterways.

Methods

Yellow oleander near Mingela, velvety tree pear near Inglewood and pond apple near Babinda are treated with the EZ-Ject herbicide lance in split-plot design experiments with the herbicide as the main plot (glyphosate and imazypyr) and the number of cartridges as the sub-plot (0, 1, 2, 3 and 4 shells). We replicate each treatment four times and the experimental unit consists of 15 plants. All treated plants have a basal diameter of 10–15 cm. We assess plants 1, 6 and 12 months after treatment using a damage rating scale and determine plant mortality at the final assessment.

Progress

Preliminary results indicate that imazapyr is more effective than glyphosate. The trial is still ongoing. A final report for this project will appear in *Technical highlights 2009–10*.

Funding in 2008–09

Queensland Government

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

Project dates

July 2007 – June 2010

Project leader

K. Dhileepan, Alan Fletcher Research Station
Tel: (07) 3375 0721
Email: kunjithapatham.dhileepan@deedi.qld.gov.au

Other staff

Bill Palmer, Di Taylor, Matthew Shortus, Catherine Lockett, Kirsty Gough, Kelli Pukallus, Tricia Voigt and Karina Pyle (QUT honours student)

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 bellyache bush rust fungus (*Phakopsora jatrophicola*) as a potential biocontrol agent for bellyache bush.
- Evaluate the ability of bellyache bush to respond to simulated herbivory and identify the type and frequency of herbivory that will be required to reduce its growth and vigour.

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. Yet, 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.

There is no information on the susceptibility of bellyache bush to herbivory. Results from simulated herbivory studies will help to identify whether all the bellyache bush populations in Australia are equally susceptible to damage, and if not, which populations and what morphological parts of the plant are best targeted by biological control.

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 (Columbia, Venezuela, Ecuador, Brazil, Argentina, Paraguay and Bolivia) and the Caribbean (Puerto Rico, St Kitts and Dominica).

Surveys for potential agents in Cuba are conducted by Stefan Neser of the Plant Protection Research Institute, South Africa.

CABI in Mexico, in collaboration with staff from the CSIRO Mexican Field Station, conducts surveys for the presence of spores of the rust fungus (*P. 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 suitably 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.

The bellyache bush stem-boring weevil (*Cylindrocopturus imbricatus*) is imported from Mexico into the AFRS quarantine facility for rearing and host-specificity testing. Preliminary host-specificity of the rust fungus (*P. jatrophicola*) is carried out at CABI Europe-UK using test plants supplied by AFRS. If the results are encouraging, we carry out a detailed host-specificity test involving all approved test plants.

Ecological studies

Simulated herbivory is imposed on the Queensland bronze variety of bellyache bush in the field at Charters Towers. We assign field plants (seedlings, mature and old plants) to three simulated herbivory treatments (defoliation, shoot tip damage, and defoliation + shoot tip damage) at varying frequencies (no herbivory; single, two and three events of herbivory). Defoliation involves manual removal of all leaves and shoot tip damage is inflicted by cutting 5 cm of shoot tips of all branches. We then record the plant height, number of branches, number of leaves, number of flowers, number of seed capsules and basal stem diameter every six to eight weeks. Approximately eight weeks after the final

Photo 1. Field incidence of Phakopsora jatrophicola *on bellyache bush in Mexico; a) general aspect of an infected plant and b) close-up of the lower leaf surface bearing uredinia. (Photos courtesy of Marion Seier, CABI Europe-UK.)*

herbivory treatments, we harvest all surviving plants and record various plant parameters (plant height, basal stem diameter, number of branches, number of leaves, number of seed capsules and plant biomass).

An honours research project evaluates how different bellyache bush populations (Queensland bronze, Western Australian green, Katherine green and Darwin purple) in Australia respond to simulated herbivory. We assign potted plants from field-collected seedlings of various bellyache bush populations to two herbivory treatments (defoliation and shoot tip damage) at varying frequencies (no damage; one, two and three events of damage). We then record the impact of damage on plant growth (shoot length, basal stem diameter, number of leaves and number of branches) and ecophysiology (photosynthesis and stomatal conductance) every five weeks. At the end of the trial, we harvest all plants and record various plant parameters (shoot length, basal stem diameter, number of branches, number of leaves and plant biomass).

A third study examines the differences in various ecophysiological parameters (photosynthesis, stomatal conductance and transpiration rates) 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 LICOR LI-6400 portable photosynthesis system in the glasshouse.

Progress

Native range surveys

In 2008, parts of Paraguay and Bolivia that are climatically similar to invaded areas in Australia were surveyed. Evidence suggested that bellyache bush is not native to these regions and no new potential bellyache bush agents were identified.

Field trips were also conducted within Mexico and Venezuela to collect the stem-boring weevil (*C. imbricatus*) and the rust fungus (*P. jatrophicola*) for host-specificity tests.

Field surveys conducted in Mexico across 11 sites in Veracruz region during October–November 2008 showed widespread infection by the rust fungus in *J. gossypiifolia*, with uredinospores being the prevalent spore stage. Teliospores were not detected in the field. Field collections have been sent to the UK for further studies. There was no evidence of field incidence of the rust fungus on other plant genera co-occurring with *J. gossypiifolia*.

A cercosporoid fungus (*Cercospora* sp.) has been documented to be the second most damaging pathogen on *J. gossypiifolia* in Mexico.

Host-specificity tests

At this point in time—with the exception of the rust fungus (*P. jatrophicola*) and the stem-boring weevil (*C. imbricatus*)—there appear to be few prospective biological control agents for bellyache bush.

A colony of the stem-boring weevil has been established at the CSIRO Mexican Field Station and preliminary host-specificity testing is in progress.

Initial studies of the biology and host-specificity of *P. jatrophicola* conducted under quarantine proved that the strain W2028 ex *J. gossypiifolia* is pathogenic to all Australian varieties of *J. gossypiifolia* screened. The two varieties Western Australian green and Queensland purple showed more susceptibility to the rust than the other varieties. Under quarantine conditions, the rust needs a short dew period of four hours for spore germination and

infection. The rust showed a wide temperature tolerance for spore germination and infection.

Preliminary host-specificity tests also proved that the W2028 strain is specific to species within the genus *Jatropha*. Results for inoculations of *J. curcas*, as well as cross-inoculation studies undertaken with the rust strain ex. *J. curcas* (W2482), indicated that host-specific populations of *P. jatrophicola* exist that are adapted to its various reported hosts. Hence, we decided to focus further studies on the evaluation of additional rust strains ex *J. gossypiifolia*, in order to identify a strain that is both virulent to *J. gossypiifolia* as well as highly specific to this host, for further comprehensive host range studies.

CABI has signed a contract to conduct a survey in Mexico to make a fresh collection of the rust fungus, and to ascertain its field specificity. All Australian bellyache bush varieties and other *Jatropha* species have been sent to CABI to conduct pathogenicity and preliminary host-specificity testing of the bellyache bush rust fungus.

Ecological studies

We completed the simulated herbivory field trial in June 2008 and recorded dry weights of various plant parameters during August–September 2008. Data analysis is currently in progress.

The honours research project was initiated in April 2008 and completed in November 2008. The study indicated that leaf damage was more effective in reducing basal stem diameter and total plant biomass, while shoot damage reduced plant height. Frequency of simulated herbivory was not a major factor in affecting plant response. The study also highlighted that all varieties of bellyache bush in Australia are susceptible to herbivory.

The ecophysiological study is nearing completion.

Funding in 2008–09

Land Protection Fund

Queensland Government (Blueprint for the Bush)

Collaborators

Tim Heard (CSIRO Entomology, Brisbane)

Ricardo Segura (CSIRO Entomology, Mexican Field Station)

Marion Seier (CABI Europe-UK, United Kingdom)

Tanya Scharaschkin and S. Raghu (Faculty of Science and Technology, QUT)

Stefan Neser (ARC-PPRI, South Africa)

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.

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.

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

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

Project dates

May 2007 – May 2015

Project leader

K. Dhileepan, Alan Fletcher Research Station

Tel: (07) 3375 0721
Email: kunjithapatham.dhileepan@deedi.qld.gov.au

Other staff

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

Objectives

- Monitor the field persistence and abundance of parthenium biocontrol 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 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 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 very high competitive indices would help to manage parthenium more effectively.

Methods

Biological control agent monitoring

We monitor parthenium sites in central and north Queensland 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. melampodii*), the clear-wing moth (*C. ithacae*) and the stem-galling weevil (*C. albocinereus*)—along with information on the abundance of parthenium.

Parthenium clear-wing moth rearing and release

To cater for field releases of the clear-wing moth in north Queensland, we establish a small glasshouse colony at TWRC from collections made in central Queensland.

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 320 potted plants to quantify the effect of two competitive pasture plant 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 *Zygogramma bicolorata* Pallister in two adjacent insect-proof shadehouses. Field-collected *Z. bicolorata* adults are released (two adult beetles per plant) onto the plants in one of the insect-proof shadehouses (with biological control) at six 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 *Z. bicolorata* and its damage levels at monthly intervals. Simultaneously, we monitor the shadehouse with no biological control to check that the plants are free of any agents. After three months, we harvest all plants and record various plant parameters (e.g. height, biomass, number of flowers and seed viability). We calculate competitive indices for both competitive plant species with and without the biological control agent, and identify the most competitive plant.

Progress

Sites in central Queensland were sampled in January and March 2009. Sites in north Queensland were sampled in April 2009.

Parthenium summer rust (Puccinia melampodii)

Presence of the summer rust was evident at all the three sites (Cardigan Station, Felspar and Plain Creek) in north Queensland. However, the proportion of plants (Figure 1) and proportion of leaves (Cardigan station = 39.7 ± 16.3;

Felspar 0.8 ± 1.7%; Plain Creek = 9.2 ± 2.5%) with summer rust infection varied widely between sites. In central Queensland, 9 out of 15 sites (60%) showed rust incidence and the level of rust incidence varied widely (Figure 1). Overall, the rust appears to be more widespread in the north than in the south, and more in inland areas than in coastal areas.

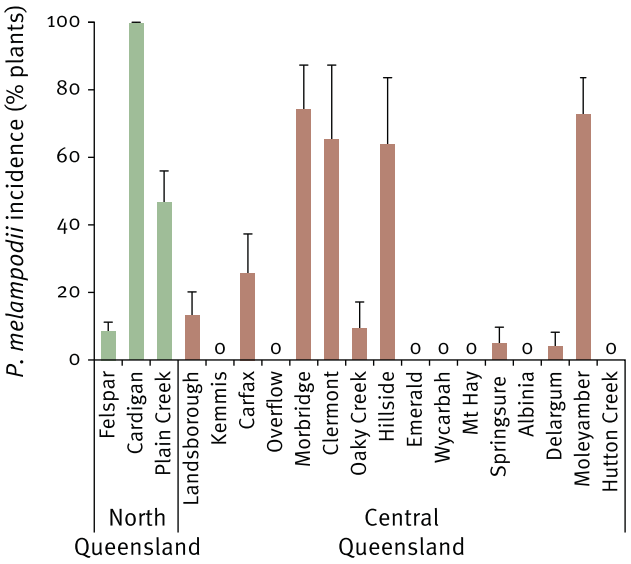

Figure 1. Incidence of Puccinia melampodii *in Queensland. (Vertical bars indicate the SE of the means.)*

Parthenium clear-wing moth (Carmenta ithacae)

Evidence of field establishment and sustained field incidence of the clear-wing moth were recorded in five (Wycarbah, Mt Hay, Long Island, Overflow and Carfax) of the 13 release sites surveyed in Queensland. At Wycarbah and Mt Hay in central Queensland, annual surveys during 2006–2009 revealed an increasing trend in the incidence of the clear-wing moth (Figure 2).

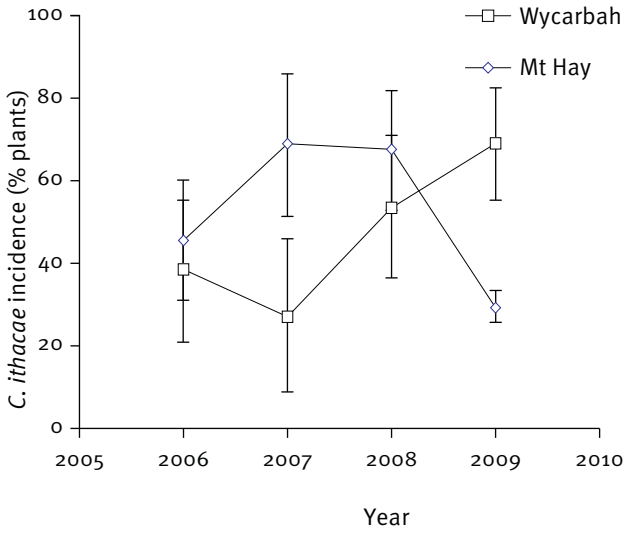

Figure 2. Incidence of Carmenta ithacae *in central Queensland. (Vertical bars indicate the SE of the means.)*

A more comprehensive survey in January and March 2009 confirmed the field establishment of the moth in other release sites (Long Island reserve, Overflow and Carfax), as well as in two non-release sites nearby (Gracemere, 20 km from Long Island and North Wycarbah, 5 km from Wycarbah) all in central Queensland (Figure 3). However, no establishment was evident in other release sites sampled in north (Cardigan, Plain Creek and Felspar) and central (Cobbadah, Delargum, Hillside, Hutton Creek, Kemmis Creek, Landsborough, Lotus Creek, Moleyamber Creek, Morebridge, Oaky Creek and Oxford Downs) Queensland.

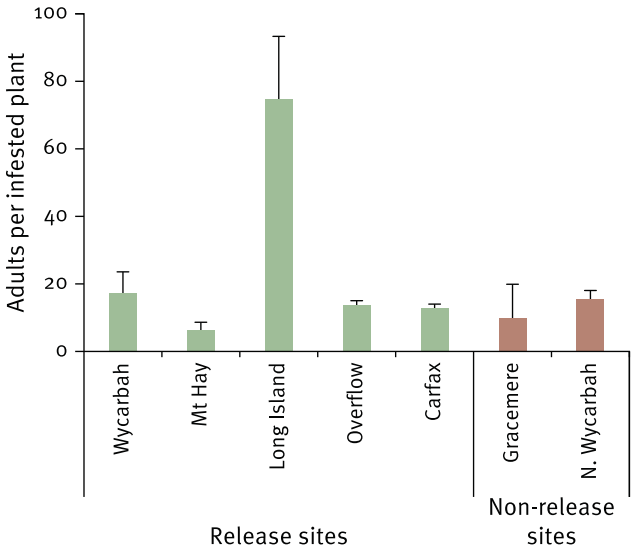

Figure 3. Abundance of C. ithacae *at release and non-release sites in central Queensland. (Vertical bars indicate the SE of the means.)*

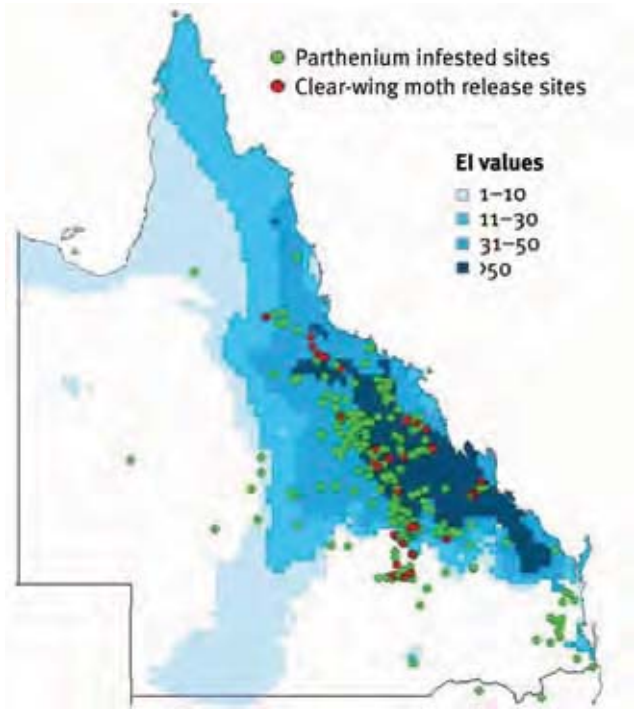

Figure 4. A CLIMEX model for C. ithacae *showing areas of suitability. Parthenium infestations and release sites of the clear-wing moth are also shown. (EI = Ecoclimatic Index, a measure of climatic suitability)*

A CLIMEX model based on the native range distribution of the clear-wing moth in Mexico predicts that coastal areas in central and north Queensland are more suitable than inland areas (Figure 4).

In January 2009, we collected 37 parthenium plants infested with the clear-wing moth from Mt Hay and Wycarbah in central Queensland. The 30 adults that emerged from these plants formed the basis of a small glasshouse colony. A second collection of around 200 plants from Carfax was made in April 2009. Also in April 2009, we released 20 potted plants from TWRC and 100 stems from Carfax in a gauze-covered field cage onto parthenium at Felspar near Charters Towers. This field cage was destroyed by cattle in June 2009 before any definite signs of insect emergence and egg laying were seen. We are currently maintaining a small colony of the clear-wing moth at TWRC but there have been insufficient insects emerging for further releases.

Parthenium stem-galling weevil (Conotrachelus albocinereus)

We did not record this insect at any of the survey sites. Limited establishment and performance of this agent could be due to the dominance of the stem-galling moth (*Epiblema strenuana*) in all parthenium infested areas in Australia. Both the stem-galling moth and the stem-galling weevil share a similar feeding niche.

Beneficial plant competition and biological control

The experiment (8 replications × 2 densities × 5 planting combinations × 2 competitive plant species × 2 biological control treatments) was initiated in October 2008 and completed in February 2009. Preliminary results suggest that defoliation by *Z. bicolorata* enhanced the competitive index values of both the native bull Mitchell grass and introduced butterfly pea legume by a factor of +0.3. Data analyses for defoliation levels, reproductive output and seed viability are in progress.

Funding in 2008–09

Queensland Government

Collaborators

Steve Adkins, Professor (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 QPIF website at www.dpi.qld.gov.au

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

Project dates

January 2007 – December 2011

Project leader

K. Dhileepan, Alan Fletcher Research Station
Tel: (07) 3375 0721
Email: kunjithapatham.dhileepan@deedi.qld.gov.au

Other staff

Syed Irfan Ahmed, K. K. Srivastava, Sangeetha Singh, Sahadev Chouhan, Naveen Sharma, Mahadeo Gorain and Anamika Sharma (AFRI)

A. Balu, M. Senthilkumar, S. Murugesan and P. Senthilkumar (IFGTB)

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*. Survey sites are predominantly forestry plantations in tank beds and isolated plants on roadside or bunds of agricultural lands. Survey methods are random and opportunistic, with different districts/areas covered in different months.

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 and cover a range of age groups from seedlings to mature trees. Other adjacent *Acacia* species are also sampled to monitor the field host-specificity of recorded insects and plant pathogens. Survey methods are more systematic, with predetermined sites sampled at quarterly intervals.

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). 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. defoliation levels, plant height, number of leaves, number of shoots, basal stem width, 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 glasshouse trials to confirm host-specificity.

Progress

Project initiation

Staff selection at both collaborating research agencies has been finalised. Three junior research fellows (two entomology and one plant pathology) were appointed at AFRI in July 2008 (Photo 1). At IFGTB, casual junior research fellows were employed in July 2008 to initiate field surveys, but regular junior research fellows (two entomology and one plant pathology) were appointed in November 2008 (Photo 2). We have also obtained approvals from relevant state forestry departments to conduct field surveys and exclusion studies in protected forest areas.

Photo 1. Project staff at the collaborating Arid Forest Research Institute, India.

Photo 2. Project staff at the collaborating Institute of Forest Genetics and Tree Breeding, India.

Native range surveys

Suitable survey sites in Rajasthan (11 sites), Gujarat (13 sites), Tamil Nadu (42 sites) and Karnataka (15 sites) states have been identified.

In Tamil Nadu, we have so far recorded 48 species of insects and 14 diseases on *A. nilotica*. Many of the insects and diseases are known to have wide host ranges. However, the host ranges of some of the insects (e.g. leaf-webbing insect) and diseases (fungi inducing galls in leaf, rachis and pods) are unknown.

Among the 14 insect species recorded so far in Gujarat and Rajasthan, insect-induced shoot galls, defoliating weevils (*Myllocerus* spp.) and bagworms (*Pteroma* sp.) were prominent and consistent across many sites. Diseases documented during the survey include ganoderma root rot (*Ganoderma lucidum*), leaf blight and leaf spot (to be identified), fusarium root rot (*Fusarium* sp.), charcoal root rot (*Macrophomina phaseolina*), heart rot (*Formes* sp.), shoot tip die back (*Botryodiplodia theobromae*), powdery mildew (*Oedium* sp.) and leaf rust (*Ravenelia* sp.). Except for the leafrust, all diseases appear to have a wide host range.

Exclusion studies

Exclusion studies have been initiated at all sites in Rajasthan, Gujarat and Tamil Nadu. Monitoring of potted plants is ongoing.

Agent prioritisation

An insect-induced shoot gall (to be identified) has been prioritised for further studies, with initial studies focusing on identification and establishing the colony in the glasshouse at AFRI.

A leaf-webber, a scale insect and a leaf-feeding beetle, all collected only on *A. nilotica*, also appear promising. Studies on their life cycles and identification are in progress at IFGTB.

We are also considering leaf, rachis and green pod galls prevalent in Tamil Nadu, all believed to be induced by the same fungus, for detailed studies. Dr Roger Shivas identified the rust fungi collected on *A. nilotica* as *Ravenelia evansii*. Attempts are currently underway to inoculate potted plants using isolated fungus in the glasshouse at IFGTB.

Funding in 2008–09

Meat and Livestock Australia ($94 000)

Land Protection Fund

Queensland Government (Blueprint for the Bush)

Collaborators

Roger Shivas, Principal Plant Pathologist (QPIF)

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.

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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 QPIF website at www.dpi.qld.gov.au

11. Biological control of weedy sporobolus grasses (*Sporobolus pyramidalis*,*S. natalensis*, *S. fertilis*, *S. africanus* and *S. jacquemontii*)

Project dates

January 2001 – October 2008 (completed)

Project leader

Bill Palmer, Alan Fletcher Research Station
Tel: (07) 3375 0748
Email: bill.palmer@deedi.qld.gov.au

Other staff

Wilmot Senaratne

Objectives

- Achieve biological control of the five weedy sporobolus grasses infesting areas of Australia.
- Determine the biology and host-specificity of two potential biological control agents—the sporobolus leaf smut (*Ustilago sporoboli-indici*) and the sporobolus stem wasp (*Tetramesa* sp.).
- Propose the release of the leaf smut and the stem wasp in Australia if proved host-specific.

Rationale

Five exotic grasses (*Sporobolus pyramidalis*, *S. natalensis*, *S. fertilis*, *S. africanus* and *S. jacquemontii*), collectively known as the weedy sporobolus grasses, are serious weeds along Australia's eastern seaboard. They are generally unpalatable, cause loss of production and ultimately lower property values. The grasses are easily dispersed and conventional methods of control are either costly or ineffective. Interest in the biological control of the weedy sporobolus grasses began in 2000.

Methods

Surveys for potential biological control agents were conducted throughout southern Africa. Two possible agents were selected for further study.

The leaf smut is studied in two phases, both conducted by Professor Mark Laing of the University of KwaZulu-Natal in South Africa. In the first phase the smut is cultured and methods for infecting plants investigated. The smut is then tested against Australian populations of all the weedy sporobolus grasses to determine whether they are susceptible, and against a small number of Australian native *Sporobolus* spp. The results of these studies determine whether full host-testing leading to release in Australia should proceed.

The study of the stem wasp is also divided into two phases. The first phase, undertaken by Mr Arne Witt of ARC-PPRI in South Africa, determines whether the insect can be reared in the laboratory. If successful, we subsequently import it into quarantine facilities at AFRS for full host-testing.

Progress

Our application to have the weedy sporobolus grasses approved as targets for biological control was finally supported by the Natural Resource Management Standing Committee (NRMSC).

Studies of the leaf smut commenced in January 2005 at the University of KwaZulu-Natal. The smut was successfully cultured and infections were observed on Australian populations of *S. pyramidalis, S. natalensis, S. africanus* and *S. fertilis*, but not on *S. jacquemontii.* However, host-range trials with the smut fungus against 10 native Australian *Sporobolus* grass species indicated that four of these developed symptoms of infection typical of the smut fungus. After consulting with 20 scientists or stakeholders, it was decided that approval for the release of the smut fungus in Australia is unlikely and further work on this pathogen was terminated.

Work on the stem wasp was also discontinued because all efforts to rear it in the laboratory were unsuccessful; this is an essential criterion for host-testing within a quarantine facility.

This project to find biological control agents overseas for the weedy sporobolus grasses has now concluded. However, Victorian scientists may progress the development of the endemic pathogen *Nigrospora oryzae* as a mycoherbicide.

Collaborators

Mark Laing, Professor and Chair of Plant Pathology, and Kwasi Yobo, Postdoctoral Fellow (University of KwaZulu-Natal, South Africa)

Arne Witt, Division Manager and Ayanda Nongogo, Student (ARC-PPRI, South Africa)

Mike Morris, Principal, Plant Health Products (Stellenbosch, South Africa)

Roger Shivas, Principal Plant Pathologist (QPIF)

Bryan Simon, Principal Botanist (DERM)

More information

Key publications

Yobo, K.S., Laing, M.D., Palmer, W.A. and Shivas, R.G. 2009. Evaluation of *Ustilago sporoboli-indici* as a classical biological control agent for invasive *Sporobolus* grasses in Australia. *Biological Control* 50(1): 7–12.

Palmer, W.A. 2008. *Biological control of weedy sporobolus grasses by two host specific agents*. Final report. Meat & Livestock Australia Limited, North Sydney. 63 pp.

Palmer, W.A., Yobo, K.S. and Witt, A.B.R. 2008. Prospects for the biological control of the weedy sporobolus grasses in Australia. 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. pp. 264–266.

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

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

Project dates

January 2000 – July 2010

Project leader

Bill Palmer, Alan Fletcher Research Station
Tel: (07) 3375 0748
Email: bill.palmer@deedi.qld.gov.au

Other staff

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.

Progress

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.

Photo 1. The weevil Alcidodes sedi *feeding on a mother-of-millions plant.*

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

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

Funding in 2008–09

Land Protection Fund

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 QPIF website at www.dpi.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

K. Dhileepan, Alan Fletcher Research Station
Tel: (07) 3375 0721
Email: kunjithapatham.dhileepan@deedi.qld.gov.au

Other staff

Olusegun Osunkoya, Di Taylor, Mariano Treviño, Jayd McCarthy, Matthew Shortus, Manu Saunders (UQ honours student) and Richard Boyne (QUT summer student)

Objective

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

Rationale

Cat's claw creeper (*Macfadyena unguis-cati*), a 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 the leaf-mining buprestid beetle (*Hylaeogena jurecki*), and also to look for new 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.

Field release and monitoring

We mass-rear and field release two biological control agents, the leaf-sucking tingid (*Carvalhotingis visenda*) and the 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. At 15 release sites in south-east Queensland (Canungra, Carindale, Coulson Creek, Crofby, Fassifern, Bardon, Latimer's Crossing, Maleny, Maroon, Moggill, Moogerah, Mooloolah, Nerang, Oxley and Pine Mountain) we also carry out detailed random quadrat surveys. Along four transects running from the release point in each cardinal direction (north, south, east and west), we count a maximum of 10 quadrats of 400 cm^2 each (20 cm × 20 cm) at 1 m intervals. Within each quadrat, we estimate percentage total leaf cover and percentage leaf damage and visually sample all leaves to count the number of adult tingids and the percentage of leaves with eggs.

Photo 1. Carvalhotingis visenda *damage on cat's claw creeper at a site near Mooloolah.*

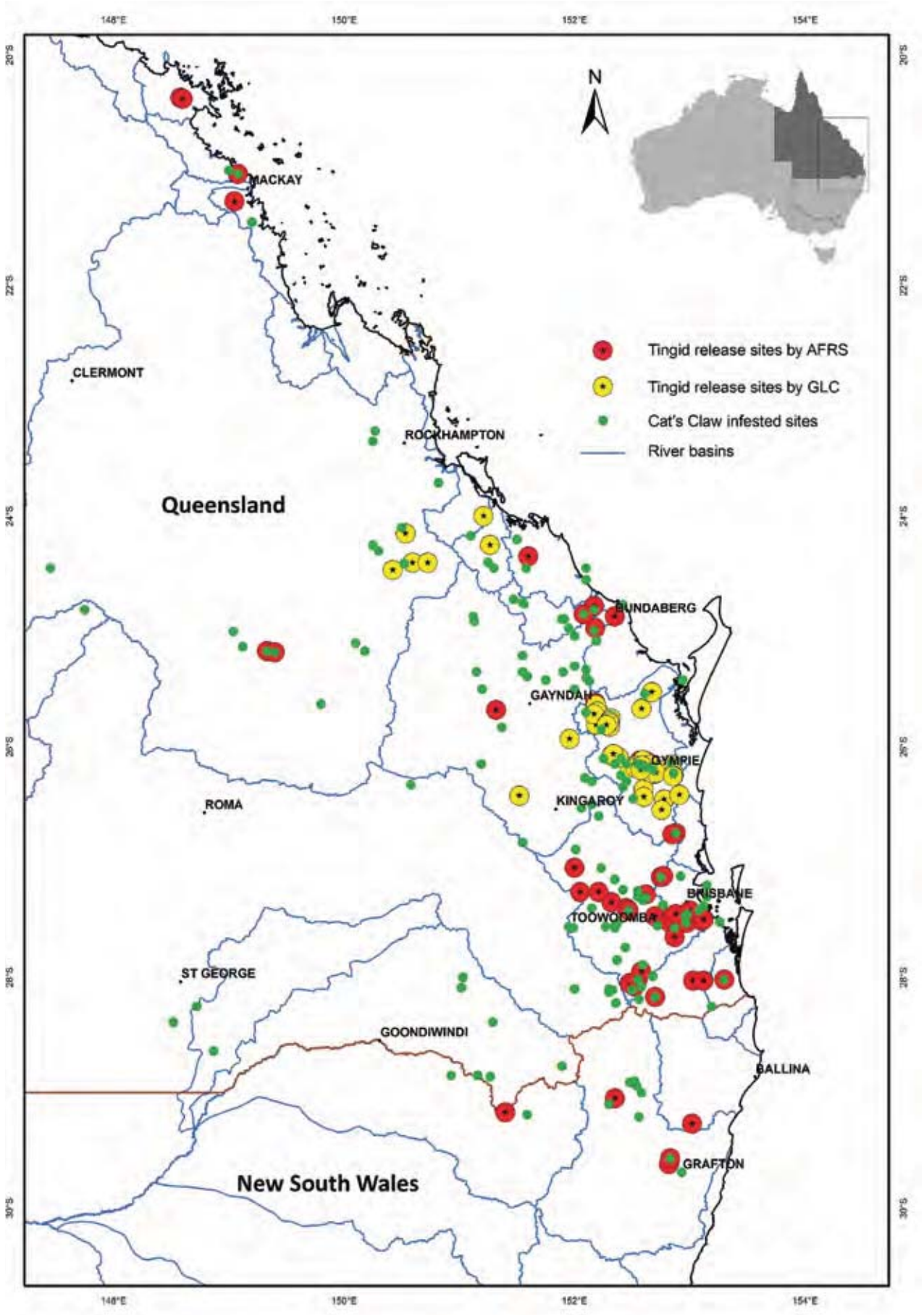

Figure 1. Current distribution of cat's claw creeper and C. visenda *release sites in south-east Queensland and northern New South Wales. (AFRS = Alan Fletcher Research Station; GLC = Gympie & District Landcare)*

Bioevaluation

In a glasshouse experiment, we study the preference (feeding and oviposition preference) and performance (larval/nymphal survival and development) of the two approved biological control agents (*C. visenda* and *H. pyrochroma*) on two morphologically distinct varieties of cat's claw creeper (long-pod and short-pod) using choice and no-choice tests in temperature controlled cabinets.

In another experiment, we study the impact of the tingid on the two varieties of cat's claw creeper at field sites in south-east Queensland. At each site, we plant similar sized cat's claw creeper seedlings (20 long pod + 20 small pod plants) in the soil and install a trellis for each vine to grow on. Half of the seedlings (10 long pod + 10 small pod plants) are inoculated with 20 tingid adults per plant (treatment plants), while the remaining 20 plants remain insect-free (controls). We then monitor all treatment and control plants at monthly intervals. In treatment plants, we record the proportion of leaves with tingid damage as well as the number of adults, nymphs and oviposition marks for all or sub-samples of leaves. Control plants are monitored to ascertain that they remain insect-free. We also 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, we remove all plants from the soil (along with the subterranean tubers and roots) and record various plant parameters including the leaf, stem, tuber and root biomass.

Ecological studies

A summer student research project investigates underground tuber traits of cat's claw creeper and its links with aboveground parameters at five infestation sites in riparian and inland vegetation (Oxley, Bardon, Carindale, Nerang and Boonah). At each site, we establish five soil sampling plots (each 25 cm × 25 cm in area and 20 cm in depth) and carefully remove soil samples, including above ground vegetation. In the laboratory, samples are sorted and established cat's claw creeper plants and seedlings carefully removed. We then take various morphometric measurements including variety (long-pod vs short-pod), underground connections (singular (genet) vs. connected to another plant via an underground rhizome/runner (ramet)), leaf number, stem diameter at the root-stem junction and at half stem length, stem length, number of stems per plant, and number and size of tubers per plant. We also randomly select 10 plants from each sampled plot and dry them at 80 ˚C for several days to constant weight for biomass determination.

Progress

Native range surveys

Surveys were conducted in Paraguay and Brazil by Dr Stefan Neser. Fresh specimens of *H. pyrochroma* and *H. jurecki* were collected to enrich the existing colonies of these agents in quarantine at ARC-PPRI in South Africa.

Additionally, a rust fungus (*Uropyxis rickiana*) and a green pod-boring weevil (*Apteromechus notatus*) were recorded on cat's claw creeper in southern Brazil. The rust produces galls on stems with uredinia and telia, as well as leaf spots with uredinia.

In February 2009, we submitted an application to import the leaf-mining buprestid beetle (*H. jurecki*) into Australia for host testing. Approval has been granted and the first shipment is expected in August 2009.

Field release and monitoring

Since May 2007, over 500 000 tingids (adults and nymphs) have been released at 72 sites in south-east Queensland and northern New South Wales. Post-release recovery surveys conducted during April–May 2008, August–September 2008 and May–June 2009 confirmed field establishment of the tingid at 80% of the release sites. Establishment, abundance and damage levels of the tingid were not influenced by the time (months) since initial releases were made, the number of tingids released, the frequency of field releases, the time (season) when releases were made or the proximity of the release site to a creek (i.e. riparian vs non-riparian sites).

An honours thesis on the field establishment and dispersal of the tingid was submitted in October 2008. The study developed a robust sampling methodology for tingid incidence and its damage levels in the field. Results suggest that dispersal of the tingid was slow, with an estimated rate of dispersal of around 0.45 m per month. The study also highlighted that damage levels were more severe when the tingid population exceeded one adult m^{-2} (Figure 2).

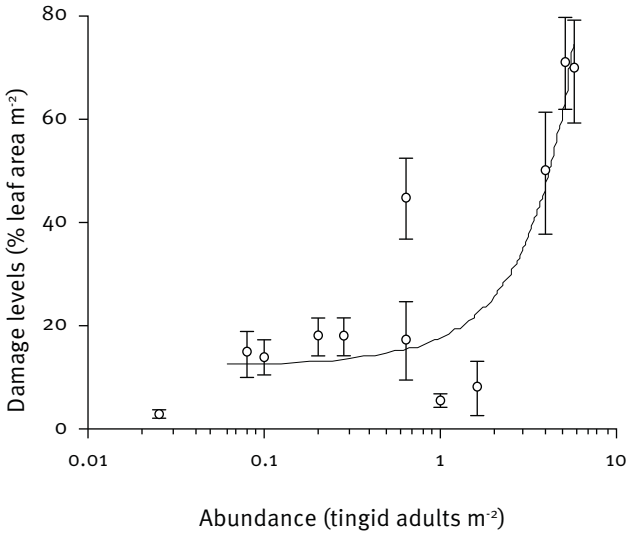

Figure 2. The relationship between C. visenda *abundance and damage levels on cat's claw creeper. (Vertical bars indicate the SE of the means.)*

Host-specificity testing of a freshly field-collected population of *C. visenda*, received from Paraguay in March 2008, was completed and approval for its field release obtained. We mixed the newly imported population with the existing glasshouse population to improve the gene pool. Field release of the rejuvenated (mixed) population is in progress.

A total of 48 000 larvae, 800 pupae, and 1200 adults of the leaf-tying moth have been released at 72 sites across Queensland and northern New South Wales. It is too early to ascertain field establishment status.

Bioevaluation

The glasshouse experiment is complete. Results suggest that both tingid and moth larvae feed and complete development on both varieties of cat's claw creeper. Further field studies confirmed that the tingid occurs on both varieties of cat's claw creeper. We are currently finalising a research paper on the results.

The field study was initiated in October 2008 and is currently in progress.

Ecological studies

The summer student research project is complete. Underground tubers were abundant in terms of density (~1000 tubers m^{-2}), although they were small in size and low in level of interconnectivity. Cat's claw creeper also exhibited multiple stems per plant. Of all traits screened, the link between stem density and tuber density was the most significant and yielded a promising bivariate relationship for the purpose of estimating, predicting and managing what lies beneath the soil surface of a given cat's claw creeper infestation. The study also suggests that new recruitment is primarily from seeds, not from vegetative propagation as previously thought. The results highlight the need for future biological control efforts to focus on introducing specialist seed- and pod-feeding insects to reduce seed output.

A field study examining various morphologically distinct leaf types on cat's claw creeper in south-east Queensland was carried out by another summer student. The study showed wide variation in leaf morphology, including the number, size and shape of individual leaflets, and the presence or absence of tendrils.

Funding in 2008–09

Land Protection Fund

Queensland Government (Blueprint for the Bush)

Collaborators

Stefan Neser and Anthony King (ARC-PPRI, South Africa)

Gimme Walter (School of Biological Sciences, UQ)

Tanya Scharaschkin and S. Raghu (Faculty of Science and Technology, QUT)

Atkinson/Buaraba Catchment Landcare Group
Brisbane City Council

Burnett Catchment Care Association

DERM/QPWS

Environmental Training and Employment Inc, New South Wales

Fraser Coast Regional Council

Gympie & District Landcare

Ipswich City Council

Moggill Creek Catchment Group

Pine Rivers Catchment Association

Oxley Creek Environmental Group

SEQ Water, Wivenhoe Dam

Sunshine Coast Regional Council

Whitsunday Landcare Catchment Association Inc.

Weed Warriors Program—Boonah, Rathdowney, Homebush and Moggil State Schools and St Bernard Primary School, Mt Gravatt

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.

Rafter, M.A., Wilson, A.J., Wilmot Senaratne, K.A.D. and Dhileepan, K. 2008. Climatic-requirements models of cat's claw creeper *Macfadyena unguis-cati* (Bignoniaceae) to prioritise areas for exploration and release of biological control agents. *Biological Control* 44(2): 169–179.

Raghu, S., Dhileepan, K. and Scanlan, J.C. 2007. Predicting risk and benefit a priori in biological control of invasive plant species: a systems modelling approach. *Ecological Modelling* 208(2–4): 247–262.

Dhileepan, K., Snow, E.L., Rafter, M.A., Treviño, M., McCarthy, J. and Senaratne, K.A.D.W. 2007. The leaf-tying moth *Hypocosmia pyrochroma* (Lep., Pyralidae), a host-specific biological control agent for cat's claw creeper *Macfadyena unguis-cati* (Bignoniaceae) in Australia. *Journal of Applied Entomology* 131(8): 564–568.

Dhileepan, K., Treviño, M. and Snow, E.L. 2007. Specificity of *Carvalhotingis visenda* (Hemiptera: Tingidae) as a biological control agent for cat's claw creeper *Macfadyena unguis-cati* (Bignoniaceae) in Australia. *Biological Control* 41(2): 283–290.

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 QPIF website at www.dpi.qld.gov.au

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

Project dates

June 2007 – May 2011

Project leader

Bill Palmer, Alan Fletcher Research Station
Tel: (07) 3375 0748
Email: bill.palmer@deedi.qld.gov.au

Other staff

Wilmot Senaratne, Liz Snow and Melinda McNaught

Objective

Achieve biological control of the environmental weed, Madeira vine, by introducing and releasing exotic insect species or pathogens.

Rationale

Madeira vine (*Anredera cordifolia*) is a South American plant that is an increasingly important environmental weed in eastern Australia. It is the only naturalised plant in the family Basellaceae in Australia, so there is a good chance that biological control agents found on Madeira vine would be sufficiently host-specific for a safe release. However, one exotic species from this family, Ceylon spinach (*Basella alba*), is grown in gardens in south-east Queensland. South African scientists led by Dr Stefan Neser have identified some promising agents, which could be 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 the Australian Quarantine and Inspection Service (AQIS) and the Department of the Environment, Water, Heritage and the Arts (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

This year, we concentrated our work on the study of the leaf beetle *Plectonycha correntina*. We continued rearing *P. correntina* without problem in the AFRS quarantine. Unfortunately, a second colony of the leaf beetle *Phenrica* sp., received in March 2008, died out in the quarantine. We are planning to import a new shipment from Argentina.

Photo 1. Plectonycha correntina *adults and feeding damage on a Madeira vine leaf.*

We developed a host-test list of approximately 30 related plant species for the host-testing of the leaf-feeding insect and submitted this for external review. After this process further species were added to the list. Almost all plants on this list were successfully sourced and cultivated at AFRS. It was necessary to apply for a DERM permit to collect some species.

Host-testing of *P. correntina* commenced in 2008. Preliminary results support the overseas host-testing and indicate that this insect should be sufficiently host-specific to be considered for release. Results indicate that *B. alba* will not be able to support populations of the leaf beetle. The beetle was also reared through to pupae on *Neopaxia australasica* (family Montiaceae) but in extremely low numbers. This result necessitated testing of additional species of Montiaceae and delayed the application for release. We have also undertaken biology studies on *P. correntina* to better understand its life history and to provide data for future modelling efforts. This insect has good reproductive potential, has several generations a year and attacks the plant as both larvae and adults. These are all characteristics of a good biological control agent.

Funding in 2008–09

Land Protection Fund

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.

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.

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.

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

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

Project dates

Ongoing

Project leaders

Michael Day, Alan Fletcher Research Station
Tel: (07) 3375 0725
Email: michael.day@deedi.qld.gov.au

Catherine Lockett, Tropical Weeds Research Centre
Tel: (07) 4761 5713
Email: catherine.lockett@deedi.qld.gov.au

Other staff

Natasha Riding, Annerose Chamberlain, Ian Johnson, Kirsty Gough, Kelli Pukallus and Tricia Voigt

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. In natural ecosystems, lantana can become the dominant understorey species, 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 in Mexico, South Africa and Europe to locate and study the biology, biotype preference and host-specificity of potential biocontrol agents prior to their introduction into quarantine in Australia.

We then import suitable agents and determine their host-specificity. Any agents approved for field release are mass-reared and released in appropriate areas with the help of Biosecurity Queensland land protection officers, DERM/QPWS officers and local government weed officers.

Progress

The lantana mirid (*Falconia intermedia*) has established at only three sites in north Queensland, despite an extensive release program throughout the state. Populations are increasing at all sites and damage is very noticeable. The agent has now spread about 20 km from some sites.

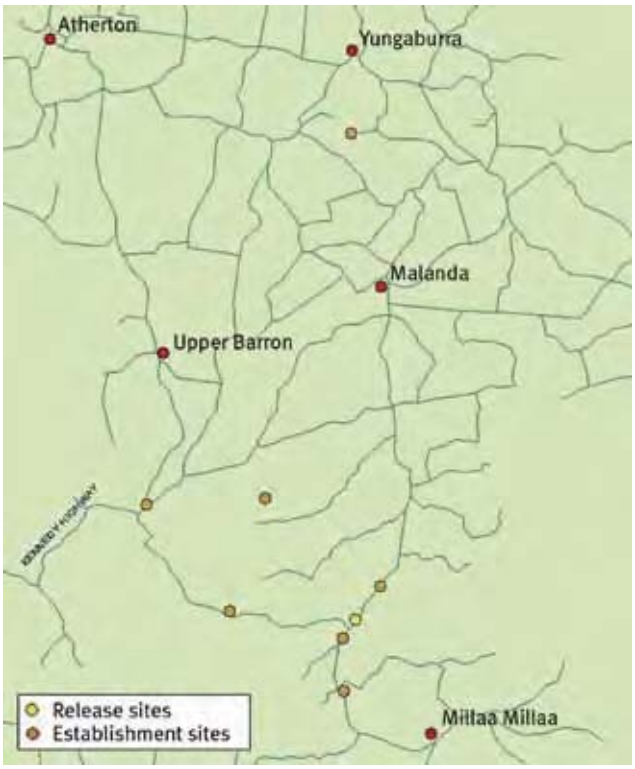

Figure 1. Current distribution of Falconia intermedia *on the Atherton Tablelands.*

We released the lantana rust (*Prospodium tuberculatum*) throughout all favourable areas in Queensland and New South Wales. The agent appears to have established at 40 sites in Queensland. Following good rains in the past few years, it has now dispersed up to 40 km from the point of release at many sites. In New South Wales, where conditions have been a little more favourable, the rust has established at 55 sites. It is widespread in northern New South Wales, spreading over 40 km from some release sites. Leaf drop due to the rust has been observed in both Queensland and New South Wales. Teliospores, the dormant stage of the rust life cycle, were found at over 30 sites.

The lantana stem-sucking bug (*Aconophora compressa*) continues to spread in Queensland and New South Wales. It has established at sites ranging from Miriam Vale to Kempsey, as well as on the Atherton Tableland and near Mt Fox and Sydney. There has been noticeable die-back of lantana branches at numerous sites, including Brookfield, Toowoomba, Mount Fox, Atherton Tableland and northern New South Wales.

We have maintained cultures of the lantana herringbone leaf-mining fly (*Ophiomyia camarae*) at TWRC and AFRS. The fly appears to be more suited to the tropical regions than south-east Queensland. To date, we have released over 80 000 individuals at over 100 sites in north Queensland. Mines have been found at nearly 60 sites and up to 4 km away from some release sites. There has been some defoliation of lantana bushes around Cooktown and at one site near Ayr. In south-east Queensland the release

program has ceased. Monitoring continues and has shown that mines now occur at only three sites.

*Photo 1. Adult lantana herringbone leaf-mining fly (*Ophiomyia camarae*).*

Photo 2. O. camarae *damage on a lantana plant at Lardelli, north Queensland.*

Figure 2. Current distribution of O. camarae *in Queensland.*

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*). The contract has been signed and we have shipped all five plant species. Initial results have found no damage to any of the test plants. However, further work is still required.

We contracted CABI Europe-UK to study the biology, biotype preference and host-specificity of the pathogen *Puccinia lantanae*. The contract has been signed and we have shipped all the required test species. Initial results found some infection on *Verbena gaudichaudii*. As a result, further testing of this and other verbena species is being undertaken. This work is due for completion by December 2009 and, if appropriate, an application seeking its release in Australia will be prepared and submitted to Biosecurity Australia and DEWHA.

Lantana herbarium specimens from many different sites in eastern Australia, previously identified by lantana taxonomist Dr Roger Sanders as either *L. urticifolia* or *L. urticifolia* X *L. camara* hybrids, have now been re-identified following Dr Sanders' visit to Kew Gardens to examine type specimens. Most of the Australian herbarium specimens were deemed to be hybrids, with five species—*L. nivea, L. camara, L. horrida, L. strigocamara* and *L. hirsuta*—implicated. Dr Sanders has identified over 100 samples from Australia and over 120 from seven countries within its native range. Interestingly, many of the samples from the native range are also hybrids.

Earlier DNA studies have suggested that Australian lantana has a close affinity to *L. urticifolia*, which has now been re-identified as *L. nivea*. A collaborative project with CSIRO Plant Industry investigates the genetic characteristics of lantana from different regions, using samples from Australia and the native range. Studies have found that there is little to separate lantana taxa within the same subsection (Camara), and that they could constitute one large but variable species. Considering that some biocontrol agents show preferences for different lantana varieties, and that different varieties have different levels of toxicity, further work is required to tease the group apart. The studies also suggest that lantana from Australia has probably the closest affinity to lantana in the Caribbean and Venezuela, rather than Mexico or Guatemala.

Funding in 2008–09

Land Protection Fund

Defeating the Weed Menace ($79 000)

Collaborators

ARC-PPRI, South Africa

CABI Europe-UK, United Kingdom

Centre for Origin Research, United States

CSIRO Plant Industry

CSIRO Entomology

Department of Environment, Climate Change and Water, New South Wales

Department of Primary Industries and Fisheries, New South Wales

DERM

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 QPIF website at www.dpi.qld.gov.au

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

Project dates

July 2006 – December 2009

Project leader

Michael Day, Alan Fletcher Research Station
Tel: (07) 3375 0725
Email: michael.day@deedi.qld.gov.au

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 the Caribbean 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 m 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 subject to a national cost-share eradication program. Biocontrol of mikania vine was first attempted in the 1970s with the introduction of *Liothrips mikaniae* into the South Pacific. 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.

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-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.

Following successful mass-rearing, 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

The project commenced in Fiji in June 2006 and in Papua New Guinea in January 2007. The quarantine facilities at Koronivia Research Station in Fiji and at Kerevat in Papua New Guinea were successfully upgraded, suitable for the importation of *P. spegazzinii*. After gaining the necessary release permits, we imported the rust into both countries in November 2008. The culture died out in Fiji soon after but another culture was established in February 2009.

Photo 1. Rust pustules on young mikania plants in the quarantine glasshouse at the National Agricultural Research Institute research station at Kerevat, Papua New Guinea.

Mass-rearing of the rust in Papua New Guinea was successful, following the trialling of several techniques. We have commenced field releases, with the rust having been released at over 100 sites in eight provinces to date. Pustules have been observed on field plants at 20 sites in five provinces and some pustules have been found over 40 m from point of release after only six months. It is still too early to confirm establishment at many of the other sites.

Comparative growth studies found that under glasshouse conditions, young potted mikania plants infected with the rust grew significantly more slowly than those plants not infected (Figure 2).

Photo 2. Researchers Dr Wiwat Sua-saard (left) from the National Biological Control Research Centre, Thailand, and Annastasia Kawi from the National Agricultural Research Institute, Papua New Guinea, releasing Puccinia spegazzinii *in the field.*

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

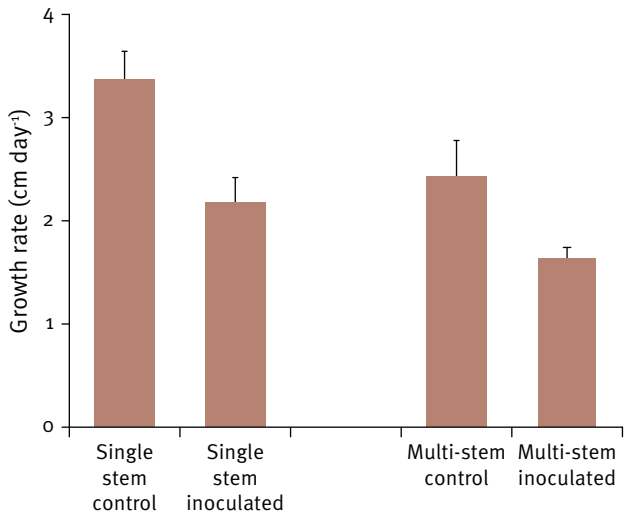

Figure 2. Effect of P. spegazzinii *on the growth rate of mikania plants under glasshouse conditions.*

An application to import the butterflies *Actinote* spp. into Papua New Guinea has been approved. Negotiations are underway on the appropriate time of importation from Indonesia. There has not been any effort to re-introduce the butterflies into Fiji.

Funding in 2008–09

ACIAR ($69 000)

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 QPIF website at www.dpi.qld.gov.au

5. Biological control of chromolaena (*Chromolaena odorata*) in Papua New Guinea

Project dates

July 1998 – December 2007 (completed)

Note: There was no report on this project in *Technical highlights 2007–08*.

Project leader

Michael Day, Alan Fletcher Research Station
Tel: (07) 3375 0725
Email: michael.day@deedi.qld.gov.au

Objectives

Introduce and establish biocontrol agents for chromolaena in 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 Papua New Guinea in biocontrol methods.

Rationale

Chromolaena (*Chromolaena odorata*) is native to the Caribbean and is now a major weed in most countries in South-East Asia, including Papua New Guinea. In Queensland, chromolaena 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. Chromolaena is a Class 1 declared weed in Queensland and is subject to a national cost-share eradication program. Biocontrol of chromolaena has previously been attempted in Indonesia and parts of the Pacific with good success. Several agents have been released, with the chromolaena gall fly (*Cecidochares connexa*) the most successful. This research project aims to introduce suitable agents into Papua New Guinea.

Better control of chromolaena in neighbouring countries such as Papua New Guinea will in turn reduce the risk of further spread into Queensland. A greater understanding chromolaena 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 Papua New Guinea, and request import permits. On approval, we import nucleus colonies of suitable agents into Papua New Guinea. Quarantine colonies are established at Bubia, Morobe Province, where insects are reared through one generation before being transferred to rearing facilities at Labu, Morobe.

Following successful mass-rearing, we field release agents throughout areas of Papua New Guinea where chromolaena 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, populations increase, spread and impact on chromolaena.

Progress

The chromolaena gall fly (*Cecidochares connexa*) was released in all 13 provinces where chromolaena is present and has established in 12 provinces. In the other province, the small patch of chromolaena was slashed and burnt. The fly has spread up to 100 km in four years from some release sites, causing substantial damage to chromolaena. Chromolaena is reported to be under control in over one-third of all sites, covering eight provinces, with the most noticeable being in East New Britain, New Ireland and Morobe. Information is not available for all areas. Food gardens have been re-established in some areas where chromolaena was once present.

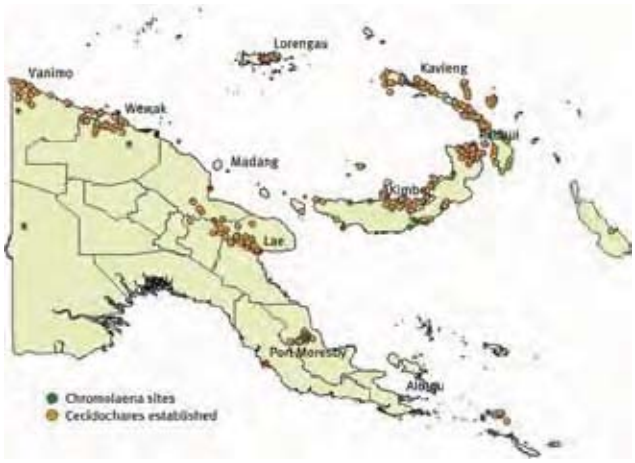

Figure 1. Current distribution of chromolaena and Cecidochares connexa in Papua New Guinea.

At various sites in Morobe, where chromolaena and the gall fly were monitored regularly, the average cover of chromolaena has decreased by 95%, with many plants killed by the gall fly (Figure 2).

The chromolaena moth (*Pareuchaetes pseudoinsulata*) was released in eight provinces but has established only in Morobe and Eastern Highlands. The moth is now found at over 20 sites, causing seasonal defoliation of chromolaena.

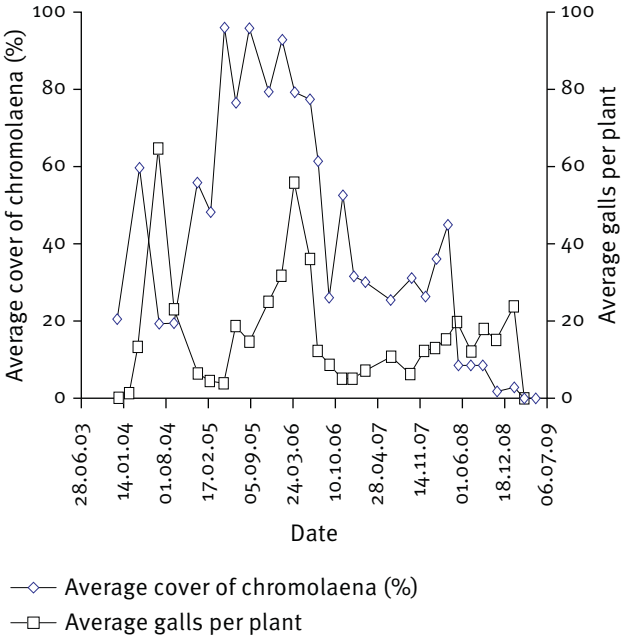

Figure 2. Average cover of chromolaena and average number of galls per plant at Trukai, Papua New Guinea.

The chromolaena leaf-mining fly (*Calycomyza eupatorivora*) was imported into Papua New Guinea several times from South Africa but failed to establish at any site. We believe that conditions may be too hot for the fly.

Collaborators

ACIAR

National Agricultural Research Institute, Papua New Guinea

Papua New Guinea Oil Palm Research Association

ARC-PPRI, South Africa

More information

Key publications

Zachariades, C., Day, M.D., Muniappan, R. and Reddy, G.V.P. 2009. *Chromolaena odorata* (L.) King and Robinson (Asteraceae). In: *Biological control of tropical weeds using arthropods*. R. Muniappan, G.V.P. Reddy and A. Raman, eds. Cambridge University Press, Cambridge pp. 130–162.

Day, M.D. and Bofeng, I. 2008. Biocontrol of *Chromolaena odorata* in Papua New Guinea. In: *Proceedings of the Seventh International Workshop on the Biological Control and Management of Chromolaena odorata and Mikania micrantha*. P.-Y. Lai, G.V.P. Reddy and R. Muniappan, eds. National Pingtung University of Science and Technology, Taiwan. pp. 53–67.

6. Biological control of two weeds in East Timor

Project dates

January 2005 – December 2008 (completed)

Note: There was no report on this project in *Technical highlights 2007–08* due to civil unrest in the country delaying progress.

Project leader

Michael Day, Alan Fletcher Research Station
Tel: (07) 3375 0725
Email: michael.day@deedi.qld.gov.au

Other staff

Annerose Chamberlain and Natasha Riding

Objectives

Introduce and establish biocontrol agents for chromolanea and *Mimosa diplotricha* in East Timor to:

- reduce the impact of the two weeds to small block holders and plantation owners in areas where they are problems
- 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 East Timor in biocontrol methods.

Rationale

Chromolaena (*Chromolaena odorata*) is native to the Caribbean and is now a major weed in most countries in South-East Asia. In East Timor, chromolaena is widespread and can form dense impenetrable monostands, crowding out all other vegetation and severely affecting food security and biodiversity. In Queensland, chromolaena 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. Chromolaena is a Class 1 declared weed in Queensland and is subject to a national cost-share eradication program. Biocontrol of chromolaena has previously been attempted in Indonesia and parts of the Pacific with good success. Several agents have been released, with the chromolaena gall fly (*Cecidochares connexa*) the most successful. This research project aims to introduce *C. connexa* into East Timor.

*Photo 1. Adult chromolaena gall fly (*Cecidochares connexa*).*

Giant sensitive plant (*Mimosa diplotricha*) is a thorny shrub that can invade food gardens and roadsides, impacting on productivity and the movement of people. *M. diplotricha* is a Class 2 declared weed in Queensland and, as such, is targeted for active control. The mimosa psyllid (*Heteropsylla spinulosa*) was introduced and released into Queensland in 1975, and is successfully controlling the plant in some areas. The psyllid has also been introduced into Fiji, Western Samoa and Papua New Guinea. This research project aims to introduce *H. spinulosa* into East Timor.

*Photo 2. Mimosa psyllids (*Heteropsylla spinulosa*).*

Better control of the two weeds in neighbouring countries such as East Timor will in turn reduce the risk of further spread into Queensland. A greater understanding of the two weeds and their biocontrol agents will also boost the state's capacity to respond to new incursions.

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 East Timor, and request import permits. On approval, we import nucleus colonies of suitable agents into East Timor, where the insects can either be reared or released directly into the field.

Following successful mass-rearing, we field release agents throughout areas of Papua New Guinea where chromolaena and *M. diplotricha* are a problems. University staff and students 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, populations increase, spread and impact on the two weeds.

Progress

The mimosa psyllid *H. spinulosa* was reared at AFRS and shipped or hand-carried to East Timor five times. Adults and nymphs were released directly into the field at various sites around and near Dili. Subsequent monitoring found that the psyllid has established at most release sites and has spread up to 20 km from point of release.

Photo 3. H. spinulosa *damage on a Mimosa diplotricha plant.*

The chromolaena gall fly (*C. connexa*), which was first introduced into East Timor in 2005, continues to spread from areas where it has established. At various sites, especially at Baucau, branches are dying and plants are becoming stunted.

Figure 1. Current distribution of chromolaena and C. connexa *in East Timor.*

Funding in 2008–09

ACIAR, via Charles Darwin University ($7000)

Collaborators

ACIAR

Charles Darwin University, Northern Territory

Ministry of Agriculture, Forestry and Fisheries, East Timor

National University of East Timor

Cassowary Coast Regional Council

More information

Key publications

Zachariades, C., Day, M.D., Muniappan, R. and Reddy, G.V.P. 2009. *Chromolaena odorata* (L.) King and Robinson (Asteraceae). In: *Biological control of tropical weeds using arthropods*. R. Muniappan, G.V.P. Reddy and A. Raman, eds. Cambridge University Press, Cambridge pp. 130–162.

Day, M.D. and Bofeng, I. 2008. Biocontrol of *Chromolaena odorata* in Papua New Guinea. In: *Proceedings of the Seventh International Workshop on the Biological Control and Management of Chromolaena odorata and Mikania micrantha*. P.-Y. Lai, G.V.P. Reddy and R. Muniappan, eds. National Pingtung University of Science and Technology, Taiwan. pp. 53–67.

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

7. Weed eradication feasibility and program evaluation

Project dates

July 2003 – June 2010

Project leader

Dane Panetta, Alan Fletcher Research Station
Tel: (07) 3375 0735
Email: dane.panetta@deedi.qld.gov.au

Other staff

Simon Brooks, Shane Campbell, Kirsty Gough, Christina Lockett, Stephen Setter and Katie Patane

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 a stochastic dynamic model that provides an estimation of program duration and total program costs.

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.

We further undertake investigations into the age to maturity, recruitment and soil seed bank rundown for *M. calvescens* and limnocharis under field conditions to support the local eradication efforts. Additional ecological data on clidemia, Siam weed and *M. calvescens* are presented in the following project report, '8. Ecology of Wet Tropics weeds' (page 45).

Progress

Siam weed database

The Siam weed database provides information on many variables, including weed density, plant counts, seeding plants, net treated areas and work effort. These are used to create indicators of eradication progress. Analysis of these data demonstrates that 80% of infestations were in the control phase in May 2009. Although the number of infestations has more than doubled since 2003, the percentage of infestations in the monitoring phase (i.e. without detection of plants for at least 12 months) has increased slowly.

'Four tropical weeds' database

Using measures of eradication progress published in Brooks et al. (2008) and Brooks et al. (2009) (see key publications below), data from visits to mikania vine, limnocharis, clidemia, *M. nervosa* and *M. racemosa* infestations have been analysed and used in the annual reporting of the National Four Tropical Weeds Eradication Program.

Information has also been collated to publish the number, type, extent and status of *M. calvescens* locations in Australia. Of the 50 known locations in 2008, 25 show evidence of naturalisation. Most infestations are in an active control phase through ongoing recruitment from a persistent seed bank.

Search effort, costs and population information from a current *M. calvescens* infestation were also incorporated into a model developed by University of New England staff as an example of using economic, management and ecological information to determine eradication feasibility and time frames.

Miconia calvescens field studies

Ecological field studies have continued for *M. calvescens*, including collation of population data and monitoring of emergence and growth in plots at an infestation near El Arish. We have used plant morphology and growth data to determine size at maturity under local conditions. Two out of 15 plants tagged at 2.5–3 m tall in September 2004 produced flowering panicles early in 2008 and were controlled, with basal diameters between 7.2 cm and 8.1 cm. These data and the sizes of 55 reproductive and 650 non-reproductive plants indicate that *M. calvescens* matures over a range of basal diameters (between 4 cm and 8 cm) (Figure 1). The three plants observed as mature at less than 5.1 cm basal diameter had been damaged. Growth data show that the fastest growing plants can increase in basal diameter at 1.5 cm per year (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 biannual surveys should present two or more opportunities to detect plants before they mature.

We undertook annual sampling of the soil seed bank in an area with high density of *M. calvescens* (prior to control) at the El Arish infestation from 2004 to 2008. Future sampling will be more widely spaced to determine soil seed bank decline over time. Despite the 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. As a suitable germination regime has been determined, we will test the viability of soil-borne seed once the 2008 samples are processed. We will also use this germination regime to screen for depletive or stimulatory seed treatments.

Limnocharis field studies

We collected seed from 400 plants at a new infestation in November 2007. This material stored well and was used to develop a limnocharis germination test in November 2008 and commence screening for depletive seed treatments in 2009. There is no published test for assessing seed viability, but over 90% of stored seed germinated when immersed in a 0.1% solution of gibberellic acid filling a 2 mL centrifuge tube and incubated on a 12 hr day/night 22/32 ˚C light and temperature regime.

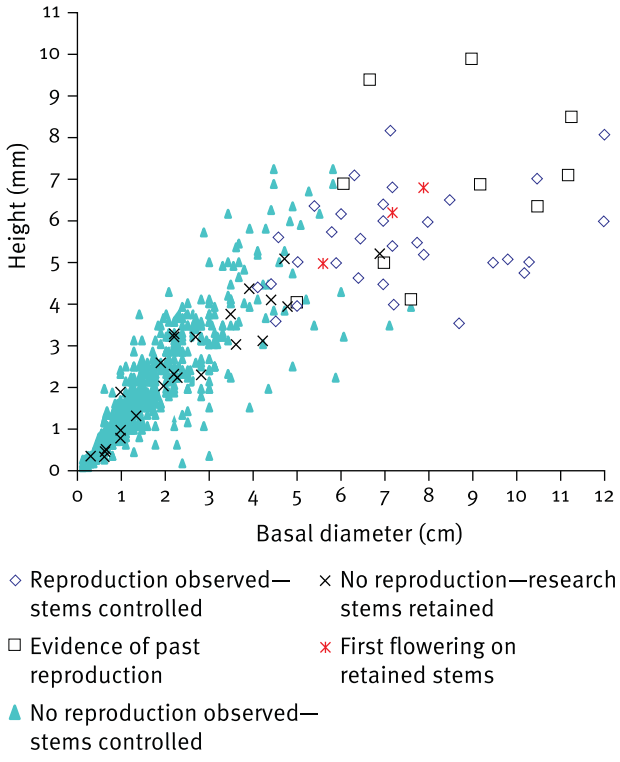

Figure 1. Height and diameter of mature and immature Miconia calvescens *plants.*

Seed bank studies are continuing at an infestation in a constantly wet, spring-fed, lowland tropical stream near Feluga. These data will guide the length of control and monitoring activities as there is no other information available on limnocharis seed persistence. We measure seed bank decline by extracting seed from soil cores collected in August 2003 and annually from 2005 to 2008. The viability of seed extracted from the 2005–2008 samples was tested in early 2009. Data from the test show seed has been extracted at similar densities and viabilities across all years. Notably the 2008 samples still contain a similar density of viable seed to earlier samples, 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 persistent seed bank.

Modelling duration and cost of weed eradication programs

The modelling approach is built upon relationships between the following parameters:

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

It also incorporates expenditure data from current eradication programs.

We applied the model to the branched broomrape (*Orobanche ramosa*) eradication program currently underway in South Australia. This program commenced in 1999 and currently 7450 ha are known to be infested with the weed. To date none of the infestations have been eradicated. Given current methods and current (2008) levels of investment, model predictions are that it would take, on average, an additional 73 years to eradicate this weed at an average additional cost (net present value) of $67.9 million (figures 2a–c). When the model was run for circumstances occurring in 2003 and 2006, the average program duration and total cost (net present value) were predicted to be 159 and 96 years, and $91.3 million and $71.5 million, respectively. The reduction in both estimated program length and total cost can be considered to represent progress towards the eradication objective, although clearly eradication of this species remains a long-term prospect.

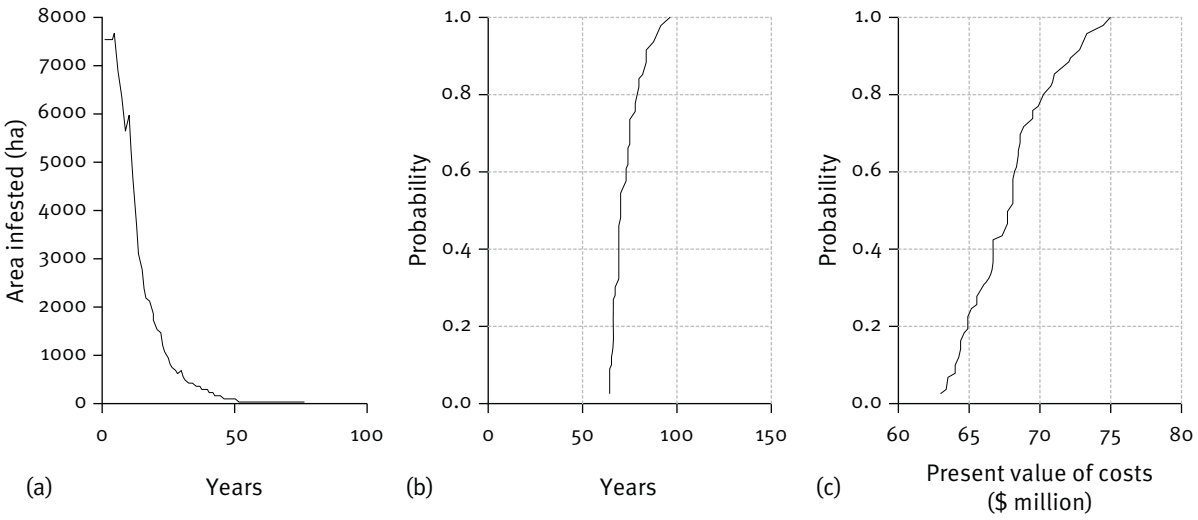

Figure 2. Predicted trend in total infested area (a) and cumulative distribution functions for (b) time to eradication and (c) total program cost of the branched broomrape eradication program in South Australia.

Funding in 2008–09

Weeds CRC ($26 000)

DAFF ($25 000)

Queensland Government

Collaborators

Oscar Cacho and Susie Hester (University of New England)

Biosecurity Queensland land protection staff based at South Johnstone and local government pest management officers provided data for eradication case studies.

Ecological studies of Class 1 weed eradication targets are conducted under the Ecology of Wet Tropics weeds project at South Johnstone and by CSIRO Sustainable Ecosystems staff in Atherton.

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.

Long, R.L., Steadman, K.J., Panetta, F.D. and Adkins, S.W. 2009. Soil type does not affect seed ageing when soil water potential and temperature are controlled. *Plant and Soil* 320(1-2): 131–140.

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.

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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 QPIF website at www.dpi.qld.gov.au

8. Ecology of Wet Tropics weeds

Project dates

January 1999 – January 2012

Project leader

Melissa Setter, Tropical Weeds Research Centre
Tel: (07) 4064 1136
Email: melissa.setter@deedi.qld.gov.au

Other staff

Stephen Setter and Katie Patane

Objective

Increase our understanding of the ecology of key Wet Tropics weeds in order to improve their management.

Rationale

Weeds are a major threat to the high economic, environmental and social value 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 destructiveness. Much of the basic ecological knowledge required to develop comprehensive long-term control strategies for Wet Tropics weeds is unknown. 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 the weed impacts on natural ecosystems, primary industries and tourism.

Methods

Field, shadehouse and laboratory experiments are underway on a number of weed species, including pond apple (*Annona glabra*), harungana (*Harungana madagascariensis*), hymenachne (*Hymenachne amplexicaulis*), Siam weed (*Chromolaena odorata*), miconia (*Miconia calvescens*), clidemia (*Clidemia hirta*), mikania (*Mikania micrantha*), tobacco weed (*Elephantopus mollis*) and neem (*Azadirachta indica*).

Photo 1. Experimentalist Stephen Setter with a hand-pulled Siam weed plant (roots in fork of tree).

Miconia—timing of flowering and fruit maturity

We have monitored five miconia trees since 2005 to assess timing and volume of fruit production, which has not been previously well documented under Australian conditions. 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.

Clidemia—fruit and seed production

We conduct a pot trial under controlled conditions in the Wet Tropics to quantify the amount of fruit and seed produced by clidemia.

Pond apple ecology

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

Neem spread

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

Progress

Miconia—timing of flowering and fruit maturity

The majority of flowering commences in the early wet season (January–April) and it takes on average 130 days (four months) for the first mature fruit to be produced.

Mature fruit will generally only be on the plant for a month before they begin to drop. Birds eating mature fruit are believed to be the most important dispersal vector. We have recorded small amounts of flower production outside this period, demonstrating the vigilance required in reducing the opportunity for miconia to reproduce.

Measures of fecundity have shown an average of 300 fruits per flower panicle (range 13–1141) and about 190 seeds per fruit. We are also investigating the number of fruit per tree, but results are not yet available.

Clidemia—fruit and seed production

Clidemia plants were capable of producing on average 284 fruits per plant (standard deviation (SD)=195, n=18) during the first six months of reproductive maturity (initial fruiting) and an average of 967 fruits per plant (SD=215, n=10) during the first 12 months. The average number of seeds produced per fruit was 801 (SD=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.

Pond apple—seedling mortality and age to reproduction

Of 520 seedlings tagged in the field only 10% survived the first two years. The shortest time to reproduction has been recorded in the field at 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 1.5 years. Monitoring is ongoing.

Pond apple—fruit production

Pond apple's fruiting generally peaks during December–April, with total seed production varying greatly between years and locations. The maximum recorded in one season to date has been 8 million seeds ha^{-1} within a dense infestation.

Control activities may be best conducted in June–August as pond apple displays yellow or senescent leaves during this period, facilitating easy location of plants. This time of year is also highly suitable due to maximum site access (dry season) and to prevent fruiting in the summer months.

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

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

Pond apple—seed longevity in water

Seeds placed in fresh water remained germinable for up to two years and eight months. After three years they had all expired. Seeds placed in saltwater retained 49% germinability after three years but we expect that all seeds will have expired after four years (sampling in February 2010).

Neem spread

Within six years, the initial canopy cover of neem of 23% (2002) has increased to 88% (2008). While the native woody vegetation was not directly measured, anecdotal evidence suggests that there has been a notable decline in *Melaleuca* spp. occurring in this area.

Funding in 2008–09

National Four Tropical Weeds Eradication Program ($30 000)

Land Protection Fund

Queensland Government

Collaborators

Cairns Regional Council

Cassowary Coast Regional Council

National Siam Weed Eradication Program

National Four Tropical Weeds Eradication Program

CSIRO Sustainable Ecosystems

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 QPIF website at www.dpi.qld.gov.au

9. Ecology and control of Siam weed (*Chromolaena odorata*) in the dry tropics

Project dates

July 2008 – June 2011

Project leader

Simon Brooks, Tropical Weeds Research Centre
Tel: (07) 4761 5708
Email: simon.brooks@deedi.qld.gov.au

Other staff

Shane Campbell, Kirsty Gough, Ashley Owen, Stephen Setter and Katie Patane

Objectives

- Investigate the effect of repeat fires on Siam weed plants and seed banks.
- Investigate the application of low volume, high concentration applications of herbicides to remote Siam weed infestations.
- Investigate key ecological attributes influencing the eradication of Siam weed from dry tropical areas.

Rationale

Siam weed (*Chromolaena odorata*) is a Class 1 declared weed in Queensland and the target of a national cost-share eradication program. It has been controlled along the Wet Tropics coast since its discovery in 1994. Since 2003, Siam weed has been discovered in the upper Ross River and Black River catchments west of Townsville. Recently there have been more infestations discovered in the upper Herbert River catchment south of Mount Garnet. The discovery of more infestations in dry tropical areas has raised questions about the practicality of control measures on remote and steep terrain in seasonally dry areas. Fire is one option for treating large areas and this project has commenced research on the effect of repeated fires on Siam weed plants and soil seed banks. Previous research has shown that single fires cause minimal plant mortality, but it is not known whether exposure to multiple fires could be effective, as appears the case for control of lantana (*Lantana camara*).

Many of the Townsville infestations are too remote to treat with high volume foliar herbicide applications, leading to a reliance on manual control of plants. The suitability of low volume, high concentration herbicide application through a 'gas (splatter) gun' carried on a backpack is also investigated by this project.

The eradication program has also sought clarification as to whether the key biological characteristics of age to maturity and seed bank longevity are the same in seasonally drier, warmer areas as they are along the Wet Tropics coast.

Methods

We establish monitoring plots in a Townsville Siam weed infestation ahead of a controlled burn. 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. Plots will be maintained to research the effect of repeated fires.

We conduct investigations into the use of a 'splatter gun' herbicide applicator at the same site. This equipment is suited to applications in more remote or rugged areas as it can be carried in a backpack and relies on a higher concentration of herbicide in a low volume application compared with traditional higher volume foliar applicators. The 'splatter gun' has been registered for use on lantana and a range of other woody weeds.

Progress

Siam weed fire response

Monitoring plots were established ahead of a controlled burn (using aerial incendiaries) in early October 2008. Data collected from thermocouple loggers during the fire indicated that a slow hot burn moved across the slope through the plots.

Most plants were scorched but not consumed by the fire. Post-fire monitoring indicates that the fire controlled seedlings and some small plants less than 2 cm in basal diameter, but larger plants reshot from the basal ball after the fire, which is consistent with previous Siam weed fire research in the Wet Tropics.

With 89% of Siam weed seed located on the soil surface at the time of burning, it was not surprising that a significant reduction in the overall soil seed bank occurred (i.e. 72.5% reduction of surface-located seed—Table 1). There was, however, a lot of seed located on plants at the time of burning and testing of these showed that they were 58% viable. The fire did not adversely affect the viability of these seeds and eventually they would fall from the plant and add to the soil seed reserves.

Table 1. Siam weed seed density, assessed as number of seedlings emerging from soil samples taken at different depths a week before (pre-burn) and a week after (post-burn) a fire.

Sample depth	Average seed density (seeds m^{-2})	
	Pre-burn	Post-burn
Surface	472.0	134.0
0–2 cm	36.3	23.6
2–5 cm	17.4	14.5

A general reduction in the lantana cover and good recovery of grass cover was apparent after the first fire.

'Splatter gun' trial

An initial investigation into the use of a 'splatter gun' herbicide applicator was established in March 2009.

Observations suggest that low volume applications of a fluroxypyr-based herbicide with an aminopyralid and penetrant affect all Siam weed leaders, resulting in complete dieback of the plants, compared with untreated control plants. Low volume applications of glyphosate and metsulfuron-methyl herbicides were less effective, as some leaders continued to grow and eventually flower. We will conduct a full assessment of the treatments later in 2009, but the 'splatter gun' may be useful at some infestations where high volume herbicide applications are not feasible. Re-shooting burnt plants may also be targeted with this application method.

Future trials

A workshop in April 2009 to discuss Siam weed research identified future research priorities, including:

- age to maturity studies
- a dry tropics buried seed trial
- leaf toxicity research
- dispersal modelling
- testing of a surfactant to improve weed seed hygiene practices
- refining of search buffers
- Siam weed biocontrol, should a decision be made to pursue this method of control.

We have commenced planning on trials to investigate age to maturity, seed longevity in the dry tropics and leaf toxicity. 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.

Funding in 2008–09

Queensland Government

Collaborators

Biosecurity Queensland land protection staff based at South Johnstone and Townsville provided assistance with locating and accessing trial areas.

DERM staff provided assistance with the controlled burn.

More information

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

10. Class 1 weed control packages

Project dates

July 2008 – June 2013

Project leader

Joseph Vitelli, Alan Fletcher Research Station
Tel: (07) 3375 0751
Email: joseph.vitelli@deedi.qld.gov.au

Other staff

Barbara Madigan

Objective

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, 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.

Progress

Prioritisation of Class 1 weed research

A Class 1 prioritisation workshop was held in August 2008. The top four weeds identified for research 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*).

We are monitoring the reproductive period for Mexican feather grass, Mexican bean tree and badhara bush, and work is nearing completion. Initial studies indicate Mexican feather grass flowers in summer, Mexican bean tree from September to June and badhara bush from October to June.

We monitored seed production for Mexican feather grass, Mexican bean tree and badhara bush. Initial studies indicate Mexican feather grass produces ~7000 seeds per plant, Mexican bean tree › 5.2 million seeds per plant and badhara bush fruit production ranges from 319 to 21 983 fruit per plant. Seed viability for Mexican feather grass and Mexican bean tree was recorded as 90% and 30% respectively.

Photo 1. (a) Female and (b) male inflorescences of Mexican bean tree.

Investigations into the time to reproductive maturity for Mexican feather grass and Mexican bean tree commenced.

A desk top literature review of potential herbicides suitable for the control of all declared Class 1 pest plants was completed. We will now compile this list in a format that can be submitted to APVMA seeking a minor use permit for Queensland Class 1 pest plants (similar to the Environmental Permit PER11463).

Funding in 2008–09

Land Protection Fund

Queensland Government

More information

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

11. Mimosa (*Mimosa pigra*) research

Project dates

July 2008 – June 2013

Project leader

Joseph Vitelli, Alan Fletcher Research Station
Tel: (07) 3375 0751
Email: joseph.vitelli@deedi.qld.gov.au

Other staff

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.
- Evaluate herbicides for control of melaleuca regrowth in areas infested with *M. pigra*.

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 (about 100 plants) 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 efforts. 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.

Control of melaleuca regrowth

The recruitment of three melaleuca species (*Melaleuca leucadendra, M. quinquenervia* and *M. viridiflora*) at Peter Faust Dam is hindering the detection and control of *M. pigra*. We grow these three species in pots at TWRC and apply 14 herbicide treatments using the spray gantry to simulate aerial application at 200 L ha^{-1} in a complete double overpass.

The treatments are:

- triclopyr/picloram (Grazon* DS Herbicide) at 1500/500 and 3000/1000 g ha^{-1}
- tebuthiuron (10% formulation) at 4000 and 8000 g ha^{-1}
- 2,4-D/picloram (Tordon* 75-D Herbicide) at 2250/562.5 and 4500/1125g ha^{-1}
- hexazinone (Velpar® L Herbicide) 4500 and 9000 g ha^{-1}
- fluroxypyr (Starane* 200 Herbicide) at 600 and 1200 g ha^{-1}
- metsulfuron (Brush-Off® Brush Controller) at 72 and 144 g ha^{-1}
- imazapyr/glyphosate (Arsenal® Xpress Herbicide) at 1500/1500 and 3000/3000 g ha^{-1}
- a control with no herbicide application.

Progress

Seedling emergence and seed bank

We have recorded an 86% decline in the soil seed bank in the core infested area from 2002 to 2007. Soil seed viability remains high at 99%. 2008 rainfall events have seen dam levels rise to 85%, inundating the core area.

Control of melaleuca regrowth

Mortality of *Melaleuca quinquenervia* and *M. viridiflora* averaged 63% irrespective of herbicide, compared to 45% for *M. leucadendra*. Tebuthiuron and hexazinone treatments killed all melaleuca plants irrespective of species, but it is unlikely that these herbicides would be registered for use at Peter Faust Dam. Apart from tebuthiuron and hexazinone, no herbicide effectively controlled all three species. Imazapyr/glyphosate was the next most effective herbicide, controlling 78% of the treated *M. quinquenervia* and *M. viridiflora* plants and 30% of *M. leucadendra* plants. The use of a front-mounted blade plough may be the only method available to effectively control all three melaleuca species at Peter Faust Dam.

Funding in 2008–09

Queensland Government

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 QPIF website at www.dpi.qld.gov.au

12. Understanding resource use efficiency and physiology of invasive woody vines of riparian zones in south-east Queensland for improved management

Project dates

July 2007 – June 2009 (completed)

Project leader

Olusegun Osunkoya, Alan Fletcher Research Station
Tel: (0)7 3375 0756
Email: olusegun.osunkoya@deedi.qld.gov.au

Other staff

Christine Perrett, Dane Panetta, Gabrielle Vivian-Smith and Chandima Fernando

Objectives

- Provide a better understanding of the physiological mechanisms contributing to the success of a suite of invasive woody vines in south-east Queensland.
- Provide information on growth stages and environmental conditions that are appropriate for management interventions of invasive woody vines.

Rationale

Vines allocate less carbon to support (i.e. stem) tissue, and thus more or less continuously produce photosynthetic surface area. Some exotic members of this guild are invasive and have become structurally visible, forming major components along our rural waterways and disturbed landscapes, especially in forest communities.

These invasive woody climbers often displace and outcompete native species. What are the eco-physiological traits that enhance the superior growth, assumed better resource acquisition and use, and ultimately higher competitive ability of these invasive vines? Managing for desired functional traits (e.g. using native species with efficient water use and low light compensation points in restoration work) as opposed to functional groups (e.g. basing replacement choice on morphological or taxonomic similarity in restoration work) may provide a mechanistic link between plant community composition and ecosystem process, thus giving us the ability to design weed-resistant plant communities. There is a need to quantify traits relating to resource use efficiency, both under controlled conditions and in the field.

Methods

To quantify traits relating to resource use efficiency, we conduct experiments in the glasshouse using plants raised from seedlings and/or cuttings.

Four invasive woody vines are compared with their native congeneric/ecological equivalents: cat's claw creeper (*Macfadyena unguis-cati*) vs bower of beauty vine (*Pandorea jasminoides*), balloon vine (*Cardiospermum grandiflorum*) vs *Cardiospermum halicacabum*, Madeira vine (*Anredera cordifolia*) vs golden guinea flower snake vine (*Hibbertia scandens*), and white moth vine (*Araujia sericifera*) vs monkey rope vine (*Parsonsia straminea*).

We investigate the influence of soil moisture (three levels) and light (two levels) on the growth (biomass and partitioning patterns) and physiological performance of the above species. Plants are harvested at the end of the experiments. We analyse the leaves for nutrient contents (nitrogen, ash, calorific value, carbon and nitrogen isotopic fractions) to derive leaf construction cost (a measure of cost of making 1 g of leaf material) and resource (water, nitrogen and energy) use efficiencies.

Progress

Glasshouse experiments were completed during summer–autumn in 2007–08. We measured a total of 23 leaf and whole plant traits, including eight of resource capture and use efficiency:

- leaf construction cost (CC)
- specific leaf area (SLA)
- mass-based maximum photosynthetic rate (Amax)
- light use efficiency (AQE)
- instantaneous water use efficiency (WUE)
- integrated water use efficiency ($\delta^{13}C$)
- photosynthetic nitrogen use efficiency (PNUE)
- photosynthetic energy use efficiency (PEUE).

Light had a greater effect than moisture on leaf chemistry, resource capture and use efficiencies of tested invasive and native species. Calorific content (HC), leaf construction cost and carbon:nitrogen ratio were lower in the invasive group, while ash content, nitrogen, maximum photosynthetic rate, light use efficiency, photosynthetic energy use efficiency and specific leaf area were higher in this group relative to the native group. Trait plasticity, relative growth rate (RGR), instantaneous and integrated water use efficiency, and photosynthetic nitrogen use efficiency did not differ significantly between the groups. Leaf trait coordination was better in the invasive group, but the expected trade-off between water use efficiency and photosynthetic nitrogen use efficiency was more pronounced in the native group. These results demonstrate that though not all measures of resource capture and use efficiency may differ between the two groups, the higher level of trait coordination and consistent higher revenue stream of fitness traits (e.g. biomass accumulation and relative growth rate) per unit of investment (specific leaf area) or cost (leaf construction cost) in the invasive group is in line with their rapid spread in new ecosystems.

*Table 1. Growth, leaf chemistry, construction cost, light, water and energy use efficiencies of invasive and native vine species grown under two light and three moisture regimes. (NS = Not significant, * = p ‹ 0.05; ** = p ‹ 0.02; *** = p ‹ 0.001)*

Vine species	Light cond.	Leaf chemistry				Leaf resource need		Leaf resource use efficiency					Plant fitness	
		N	C	Ash	HC	CC	SLA	AQE	WUE	$\delta^{13}C$	PNUE	PEUE	Biom.	RGR
Invasive group														
C. grandiflorum	high	2.8	43.82	6.6	18.58	1.36	203.29	0.085	9.44	-26.58	74.76	147.63	64.65	1.07
C. grandiflorum	low	5.0	42.40	13.5	17.11	1.20	672.70	0.088	5.58	-31.76	85.26	351.31	2.90	0.16
Cat's claw	high	5.1	41.19	11.7	17.65	1.25	161.09	0.079	7.31	-28.86	36.52	146.70	16.25	1.06
Cat's claw	low	6.0	52.67	11.7	16.96	1.21	439.12	0.076	5.70	-29.16	34.23	183.68	0.87	0.21
Madeira	high	4.8	37.00	17.5	16.66	1.15	310.55	0.058	10.63	-28.65	48.65	199.96	34.79	0.84
Madeira	low	7.4	33.00	30.0	13.02	0.86	867.88	0.055	3.39	-33.22	44.42	383.56	2.35	0.09
White moth	high	4.9	43.62	11.0	18.89	1.35	245.33	0.049	8.99	-28.09	27.28	97.71	31.23	0.96
Native group														
C. halicacabum	high	5.9	-	9.6	19.51	1.41	315.37	-	-	-	-	-	-	-
C. halicacabum	low	5.7	-	15.7	18.48	1.27	823.76	-	-	-	-	-	-	-
Pandorea	high	3.2	46.39	7.9	20.03	1.46	198.40	0.033	8.34	-26.66	65.47	141.98	26.45	1.25
Pandorea	low	3.6	46.22	9.0	19.64	1.42	335.34	0.051	6.00	-26.87	54.48	139.94	1.46	0.40
Hibbertia	high	2.9	43.64	10.6	18.37	1.31	146.74	0.025	10.40	-29.07	26.79	59.62	33.31	0.66
Hibbertia	low	3.2	40.68	13.5	17.27	1.22	336.90	0.035	3.72	-31.49	81.78	213.42	3.79	-0.08
Parsonsia	high	5.4	39.45	10.3	19.10	1.37	167.77	0.066	9.66	-31.55	20.01	78.48	8.28	1.27
Parsonsia	low	6.4	37.76	10.9	17.76	1.31	588.45	0.058	7.65	-32.16	26.70	113.19	0.94	0.58
Summary of tests (ANOVA)														
Light effect		**	NS	**	***	***	***	NS	**	***	NS	**	***	***
Moisture effect		NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	*	NS
Group effect		***	NS	***	***	***	**	*	NS	NS	NS	*	***	NS
Direction of group difference		I › N	-	I › N	I ‹ N	I ‹ N	I › N	I › N	-	-	-	I › N	I › N	-
Overall mean value														
Invasive	high	4.90	40.60	0.13	17.73	1.25	238.19	0.06	9.18	-28.05	37.42	148.12	27.42	0.95
Native	high	3.80	43.16	0.10	19.17	1.38	170.97	0.04	9.62	-29.09	37.42	93.36	22.68	1.06
Invasive	low	6.30	41.74	0.19	15.53	1.08	643.60	0.06	4.88	-31.95	39.31	272.34	1.37	0.06
Native	low	4.10	40.72	0.11	18.42	1.31	420.23	0.05	6.01	-29.58	60.90	171.22	2.06	0.30

N = Nitrogen; C = Carbon; Ash (all %)
CC = Leaf construction cost, g. g^{-1}
WUE = Water use efficiency (instantaneous), µmol CO_2. $mmol^{-1}$ H_2o
PEUE = Photosynthetic energy use efficiency, µmol CO_2. kj^{-1}
PNUE = Photosynthetic nitrogen use efficiency, µmol CO_2. mol N. sec^{-1}
Biom. = Biomass, g
HC = Heat of combustion (calorific content), Kj. g^{-1}
SLA = Specific leaf area, cm^2. g^{-1}
$\delta^{13}C$ = isotopic carbon, a measure of integrated (long-term) WUE, %
AQE = Light use efficiency, µmol CO_2 . μmol^{-1} photon
RGR = Relative growth rate, g. g^{-1}. mth^{-1}

Among the 23 leaf and whole plant traits measured, we found, through data summary using ordination, consistent differences between the invasive and native groups in six (specific leaf area, leaf density, leaf construction cost, calorific content, ash, photosynthetic energy use efficiency). Axis I of the ordination, which captured the majority of the variation in these traits, correlated positively with fitness traits of biomass accumulation and relative growth rate (Figure 1). This is further evidence that these are indeed collections of traits that could serve as determinants of plant invasiveness. Although many of these measures require expensive technical equipment, specific leaf area and ash (which correlate significantly with the above-mentioned diagnostic traits) can quickly and easily be measured to screen for (introduced) plant species with invasive tendency and possibly assist in choosing replacement species in restoration work. The latter will involve selecting native species with traits whose magnitudes and directions are similar to the diagnostic traits of the invaders.

The studied invasive vines appear to have high nitrogen requirement, as evidenced by higher nitrogen content and subsequently lower photosynthetic energy use efficiency, especially in low light (stress) conditions. In disturbed riparian zones and forest lands prone to infestation by these invasive vines, we suggest aerial application of sucrose or saw dust in order to increase nitrogen immobilisation through increase in microbial activity and subsequently lower plant-available nitrogen. This is likely to favour species with low nitrogen requirements such as the native species studied here.

Funding in 2008–09

Queensland Government

Collaborators

Tim Blumfield and Zhihong Xu (Environmental Futures Centre, Griffith University)

More information

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

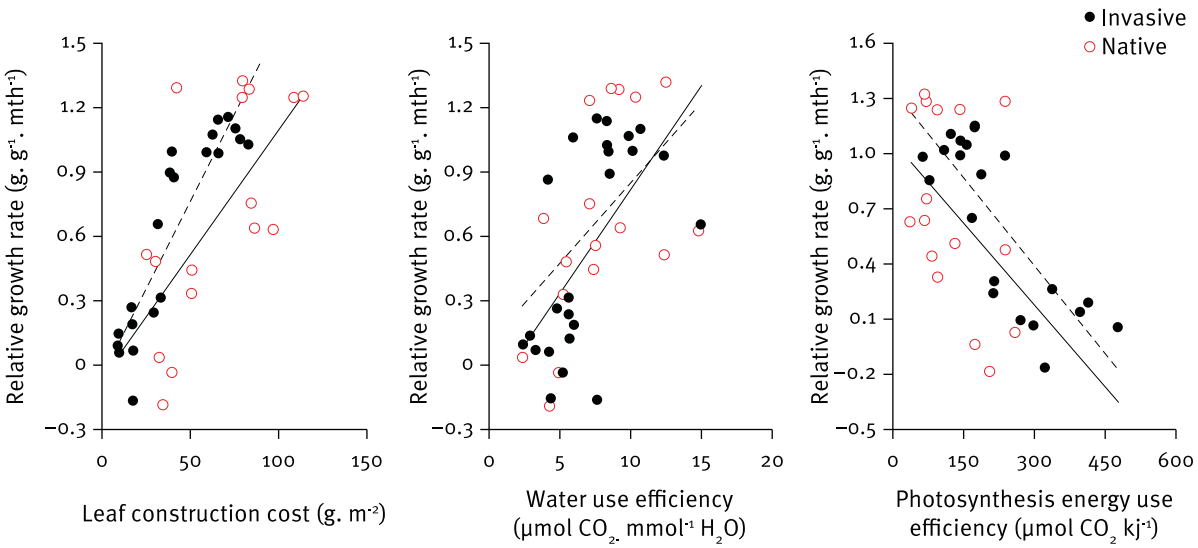

Figure 1. Dynamics of relative growth rate (RGR) in response to leaf construction cost (CC) and water and photosynthetic energy use efficiencies (WUE and PEUE) in invasive and native woody vines. The analysis indicated a greater RGR is always achieved by the invasive at any given leaf CC or PEUE. In contrast, WUE appear to play limited role in differentiation of the two groups.

13. Building population viability analysis models to gain a better understanding of control of invasive alien species: the case of *Lantana camara*

Project dates

July 2008 – June 2012

Project leader

Olusegun Osunkoya, Alan Fletcher Research Station
Tel: (07) 3375 0756
Email: olusegun.osunkoya@deedi.qld.gov.au

Other staff

Christine Perrett, Chandima Fernando and Stephen Caruana

Objectives

- Use a size-structure population matrix and mathematical modelling 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. Many biocontrol agents have been released nationally and worldwide to control the impact and spread of the species, but success has been limited. There is a dearth of quantitative data encompassing the entire life cycle of the weedy plant (Figure 1). To date, no attempt has been made to carry out any population viability analysis (PVA) studies on the species, despite the widely held view that PVA, when done in concert with sensitivity analysis and numerical simulations, could help greatly in fine-tuning management strategies for control of invasive organisms. Results from PVA studies can highlight the weakest stage/s in the life cycle of an invasive plant that can then be the focus of control efforts. This project aims to fill this apparent gap in our understanding of the invasion biology of lantana.

Methods

Demographic data on lantana is collected at four sites in the Yarraman/Blackbutt area west of Brisbane (Nanango Shire). Each of the four sites (hoop pine plantation, cattle property and natural forests open to either periodic burning or grazing regimes) contains low to moderate infestations of lantana but differs in soil properties, rainfall intensity, land-use type and weed-control practices. We set up permanent plots of 50 m × 50 m at each of four sites to parameterise the species' vital rates (seed germination and dormancy; emerging seedling, juvenile and adult growth, survival and reproduction) for projection of its population growth (Figure 1). At each site, we also collect soils beneath and away from established lantana plants to document likely impact of the weed on soil development and physicochemical properties (Table 1).

Table 1. Soil conditions in lantana populations in the Yarraman/Blackbutt area. Soil chemistry relates to nutrient levels in areas without (control) and with lantana plants. (Within a site, means with different superscript letters are significantly different at $p < 0.05$ using non-parametric t-test.)

Site	Lantana infestation stage	Soil type	Soil condition within site	Soil chemistry			
				pH	Total nitrogen (%)	Total carbon (%)	Iron (mg kg^{-1})
Cattle property open to grazing	Established	Red loam	Control	5.47	0.34	3.90	74.27
			Infested	5.20	0.35	3.94	65.43^{a}
Natural forest with grazing regime	Established	Red loam	Control	6.20^{a}	0.34^{a}	6.18	149.1^{a}
			Infested	6.97^{b}	0.46^{b}	7.95	61.13^{b}
Natural forest with burning regime	Established	Black clay	Control	6.40^{a}	0.23	4.20	42.97^{a}
			Infested	7.06^{b}	0.32	4.76	21.93^{b}
Hoop pine plantation	Re-invasion following clearing in Jan 2008	Red loam	Control	6.42	0.43	4.70	41.28^{a}
			Infested	7.03	0.49	5.80	17.20^{b}
	Overall mean		**Control**	**6.16^{a}**	**0.35**	**4.70^{a}**	**71.79^{a}**
			Infested	**6.57^{b}**	**0.41**	**5.16^{b}**	**41.43^{b}**

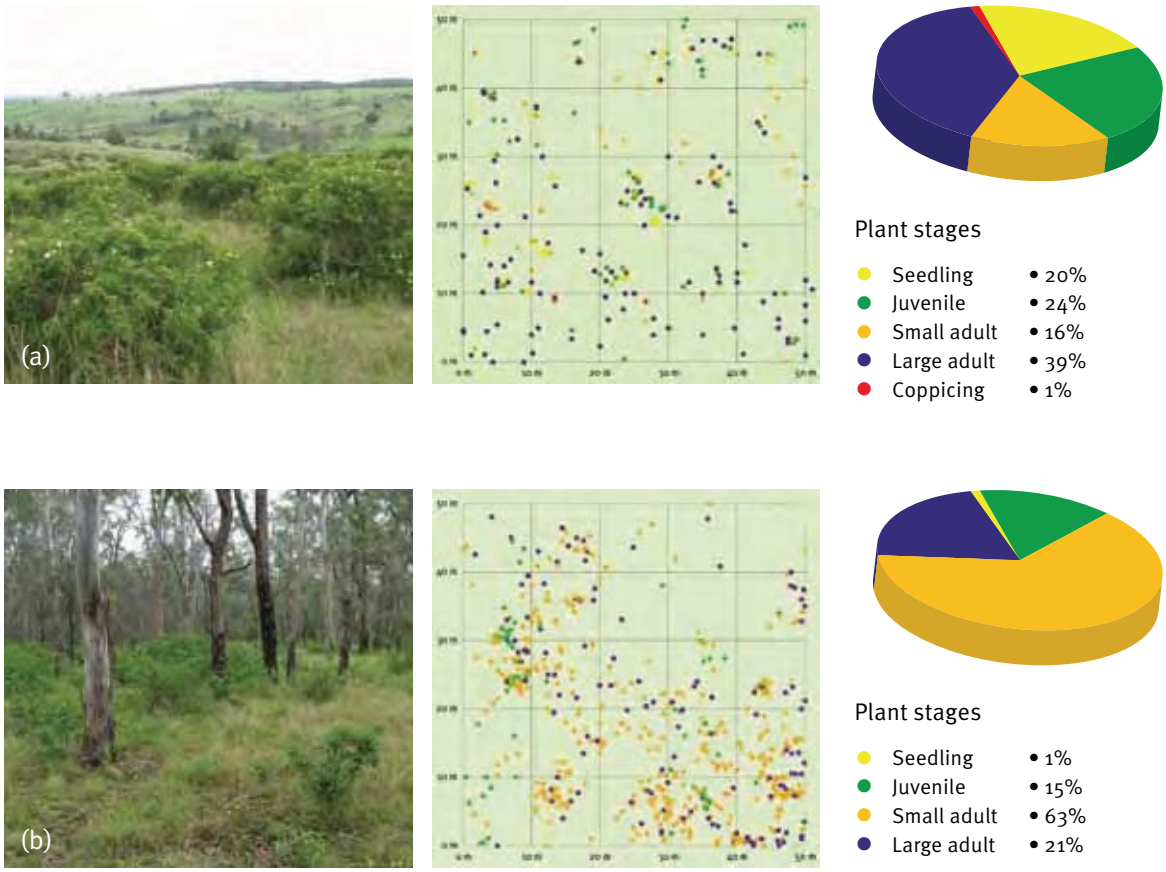

Figure 1. Lantana plants in the Yarraman/Blackbutt area (a) on a farm (cattle) property and (b) in a natural (eucalyptus) forest with a periodic burning regime. Position of individual plants in a permanent 50 m × 50 m plot within each of the sites is also shown.

Progress

Experimental set up (mapping and tagging of lantana plants in the 50 m × 50 m permanent plots) was completed between June and December 2008.

A typical life cycle of lantana is shown in Figure 2 with transitional values collected in 2008–09 for some elements of its vital rates. The soil seed bank population was low, with viability ranging from 0–8%. Seed to seedling transition was moderate, averaging 14–40%. Fecundity was high, but extremely variable across sites and adult life stages (50–4600 seeds per plant for small to medium adult plants and 2300–15 000 for large adult plants).

At one site only (hoop pine plantation), two-week-old transplanted seedlings grew in height to well over 1 m within six months and initiated flowering and fruit production, perhaps as a result of better soil condition (alkaline soil and reduced iron complexes—Table 1). This suggests that time to reproductive maturity of newly germinated seeds may be less than six months in good years. We have also initiated phenological observations on selected lantana plants and it appears that flowering and seeding may occur two to three times a year under optimal environmental conditions.

These high transition values will undoubtedly contribute to the success of the weed, but we currently do not have the full picture of the species' demographic and environmental variability to project its population growth into the future. Thus, 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 of lantana plants in each of the four sites for another two to three years.

Funding in 2008–09

Queensland Government

Land Protection Fund

Collaborators

Yvonne Buckley (Spatial Ecology Lab, UQ)

More information

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

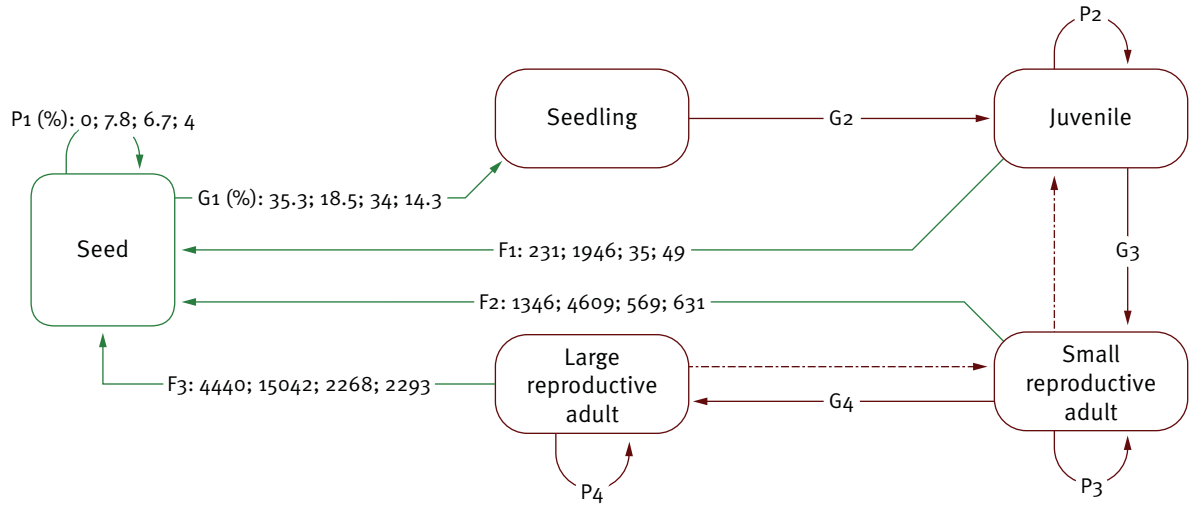

Figure 2. A simplified and hypothetical life cycle of lantana. G_n = Transition value for growth, P_n = Survival value and F_n = Fecundity/ reproduction value. Back transition (i.e. reduction in clump size or stem diameter) is possible for the reproductive adults (faint lines), especially under management regimes such as use of a biocontrol agent, herbicide or mechanical harvesting. Green circles and lines depict transitional stages with values collected in 2008–09 at each of the four sites (hoop pine plantation, cattle property and natural forests open to either periodic or grazing regimes respectively).

14. Ecology of bird-dispersed weeds

Project dates

December 2002 – December 2008 (completed)

Project leader

Gabrielle Vivian-Smith, Alan Fletcher Research Station
Tel: (07) 3375 0739
Email: gabrielle.viviansmith@deedi.qld.gov.au

Other staff

Eve White

Objectives

- Measure and better understand spatial and temporal patterns of seed rain of bird-dispersed exotic and native species in successional and restored vegetation types.
- Determine whether spatial concordance exists between seed rain, seed bank composition and seedling recruitment in a range of bird-dispersed weed (and native) species, and how this varies between vegetation types.
- Investigate contagious dispersal (i.e. whether particular bird-dispersed weeds and/or native species are associated with one another).
- Determine existing knowledge and development of novel management approaches, including the application of fruit-functional traits to identify replacement plants suitable for use in habitat restoration.
- Identify functional traits associated with bird-dispersed weeds and whether these can be applied to improve management options, including pre- and post-border weed risk assessment processes.
- Provide information on seed bank persistence and seedling recruitment for priority bird-dispersed weed species.

Rationale

Bird-dispersed weeds constitute a complex weed problem for land managers. There is little quantitative information regarding the dispersal process and rates and patterns of weed spread. Furthermore, management strategies specific to this unique mode of dispersal are only in the early stages of development.

The latter phase of this project investigates spatial and temporal patterns of dispersal and establishment of bird-dispersed weeds and native species. This knowledge will assist with the design of integrated weed management strategies, while promoting the establishment of native species.

Methods

Methodology is varied and includes:

- establishment of a seed and fruit herbarium to assist the identification of seed samples (Photo 1)
- seed trapping, soil sampling and vegetation surveys to determine seed rain, seed bank composition and seedling recruitment in vegetation types (successional vegetation and restored plantings)
- surveys of local bird observers to determine levels of existing knowledge
- fruit removal experiments measuring fruit removal rates of bird-dispersed weeds as a surrogate measure of dispersal success
- measurement of fruit traits (e.g. morphological and chemical), weed phenology and frugivore assemblages and development of a database containing this information for a range of bird-dispersed weeds
- controlled seed bank experiments to determine recruitment and seed persistence for a range of bird-dispersed weed species.

*Photo 1. Seed herbarium specimen of the bird-dispersed weed broad-leaf privet (*Ligustrum lucidum*).*

The project is located in south-east Queensland and northern New South Wales, where a wide variety of bird-dispersed environmental weeds occur.

Progress

We have now completed this seven-year project. Outputs include a range of scientific publications and fact sheets that identify ways to improve this complex weed management problem.

Research on functional traits associated with bird-dispersed weeds and their application to improve pre- and post-border weed risk assessment processes has been written up into two manuscripts. One examining traits associated with fleshy fruited invasive species and their application to the weed risk assessment process is now published online in the journal *Diversity and Distributions*. The second paper compares traits of fleshy fruited invasive species with co-occurring native species and is under review in *Biological Invasions*.

The major final research component investigated dispersal and establishment patterns of bird-dispersed weed and native species in three common early successional vegetation types: 'tree regrowth' areas dominated by camphor laurel (*Cinnamomum camphora*), shrubby 'edge' habitat ('shrub regrowth') dominated by wild tobacco (*Solanum mauritianum*) and 'native plantings' (restored sites comprised of native species). A paper describing the outcomes of this study has been published in the journal *Plant Ecology*. Results indicated that propagule availability (seed rain) was not always a good predictor of recruitment success. For example, native plantings received lower densities of invasive tree seed rain than did tree regrowth habitats, but supported a similar density of invasive tree recruits.

Photo 2. Weeds CRC Postdoctoral Fellow, Eve White, undertaking a quadrat survey of seedling recruitment in a 'tree regrowth' plot.

We analysed a subset of the seed rain data from the tree regrowth sites more intensively to investigate contagious seed dispersal. Results indicated facilitative interactions between both exotic and native species, and a paper on this work is under review in *Austral Ecology*.

We also completed analysis of seed bank persistence and recruitment data for both lantana and several invasive species of *Asparagus*. One paper has been published and a second was submitted for publication.

Funding in 2008–09

Weeds CRC ($19 000)

Queensland Government

Collaborators

Dr Carl Gosper (Weeds CRC)

Anna Barnes (Australian Rivers Institute, Griffith University)

More information

Key publications

Gosper, C.R. and Vivian-Smith, G. 2009. Approaches to selecting native plant replacements for fleshy-fruited invasive species. *Restoration Ecology* 17(2): 196–204.

Gosper, C.R. and Vivian-Smith, G. 2009. The role of fruit traits of bird-dispersed plants in invasiveness and weed risk assessment. *Diversity and Distributions* 15(6): 1037–1046.

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Buckley, Y.M., Anderson, S., Catterall, C.P., Corlett, R.T., Engel, T., Gosper, C.R., Nathan, R., Richardson, D.M., Setter, M., Spiegel, O., Vivian-Smith, G., Voigt, F.A., Weir, J.E.S. and Westcott, D.A. 2006. Management of plant invasions mediated by frugivore interactions. *Journal of Applied Ecology* 43(5): 848–857.

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Gosper, C.R., Stansbury, C.D. and Vivian-Smith, G. 2005. Seed dispersal of fleshy-fruited invasive plants by birds: contributing factors and management options. *Diversity and Distributions* 11(6): 549–558.

Stansbury, C.D. and Vivian-Smith, G. 2003. Interactions between frugivorous birds and weeds in Queensland as determined from a survey of birders. *Plant Protection Quarterly* 18(4): 157–165.

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

15. Water weed management and control

Project dates

June 2009 – June 2010

Project leader

Tobias Bickel, Alan Fletcher Research Station
Tel: (07) 3375 0737
Email: tobias.bickel@deedi.qld.gov.au

Objective

Improve the efficiency and ecological sustainability of aquatic weed control programs by better understanding the biology of high-risk aquatic weed species and their function and impacts in the aquatic ecosystem.

Rationale

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

This research aims to assist resource managers to understand and manage aquatic weeds more effectively by:

- researching the ecological and biological mechanisms that regulate aquatic plant growth and community development
- providing data on the biology of targeted species that will allow intervention at vulnerable stages of their life cycle
- investigating ecological impacts of aquatic weeds on freshwater ecosystems
- evaluating the impacts of control techniques on water quality and ecosystem functions.

Methods

In controlled pond (mesocosm) experiments, we determine the impacts of native and introduced aquatic macrophytes on water quality (oxygen, light availability, pH, temperature, nutrients) and quantity (evapotranspiration). Furthermore, we research the seasonal efficacy of registered herbicides on significant aquatic weeds.

Experiment 1 investigates the impacts of floating aquatic macrophytes on water quality and quantity in small ponds at AFRS. Ponds are either stocked with floating aquatic macrophytes of each species (four replicates) or serve as controls (water only). We measure water physicochemical parameters on a monthly basis and assess nutrient concentrations on a seasonal basis. Additionally, biomass of the plants is monitored to measure growth characteristics of the different species.

Experiment 2 is conducted in separate smaller tanks, where we treat several species of floating aquatic macrophytes with registered herbicides on a seasonal basis. After spraying with herbicides, we assess efficiency of the treatments. This includes observation of damage to plants, measurement of the amount of dead plant material and the impact of the treatment on water quality (nutrient release due to decay).

Progress

Experiment 1 was set up and commenced in June 2009. Plants used in the experiment include three exotic species: water hyacinth (*Eichhornia crassipes*), salvinia (*Salvinia molesta*) and water lettuce (*Pistia stratiotes*), and two natives: azolla (*Azolla* spp.) and duckweed (*Lemna* spp. and *Spirodela* spp. co-cultured). First measurements of physicochemical parameters were undertaken. Native and exotic floating aquatic plants both appear to have a measurable effect on the amount of light available in the water column beneath the plant cover. It can be expected that this has profound effects on aquatic ecosystems due to a reduction in primary production by planktonic and sessile algae and submerged macrophytes.

Photo 1. Experimental setup.

Measurements of pH levels in tanks with different plant species seem to corroborate this. While there were no changes in pH in tanks with heavily shading macrophytes (e.g. water hyacinth), there was a measurable increase in pH (and oxygen) in tanks with less light-intercepting plants (e.g. duckweeds). This indicates photosynthetic activity of planktonic algae in tanks with available light. There was also a reduction in oxygen levels below dense floating macrophyte cover, especially water hyacinth, most likely due to respiration of root biomass and reduction in algal photosynthesis. However, the oxygen levels are currently not critical for aquatic life.

The herbicide trial is currently set up.

Funding in 2008–09

Land Protection Fund

Queensland Government

DAFF ($24 000)

More information

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

Part 3 Pest animal management

1. Best practice baiting: dispersal and seasonal movement of wild dogs (*Canis lupus familiaris*)

Project dates

April 2006 – December 2008 (completed)

Project leader

Lee Allen, Robert Wicks Pest Animal Research Centre
Tel: (07) 4688 1397
Email: lee.allen@deedi.qld.gov.au

Other staff

Damian Byrne

Objectives

- Identify the source of current wild dog problems inside the wild dog barrier fence by monitoring the movement of wild dogs in non-baited areas within the barrier fence.
- Identify how far dispersers travel from uncontrolled areas to determine the optimum width of buffers.
- Discover the cause of increased dog activity during the April–May mating season to predict the most effective time to bait in order to prevent re-colonisation.
- Study the movement of wild dogs on and around sheep properties.

Rationale

Wild dog (*Canis lupus familiaris*) predation of livestock continues to inflict significant economic hardship for graziers and contributes to the demise of the sheep industry throughout Australia. While many stakeholders contribute considerable financial resources to wild dog management programs, wild dog problems show no sign of abating.

This project seeks to discover the source of wild dog problems inside the wild dog barrier fence and improve wild dog management by better understanding dispersal and seasonal changes in wild dog activity. The studies resulted from lengthy consultations, initiated by 14 local government stakeholders, to resolve the wild dog problems inside the barrier fence. They are designed to assist managers to determine the dimensions of buffer areas around non-baited areas, predict the most effective time to bait and better understand the behaviour of wild dogs and livestock predation.

Methods

Wild dogs are trapped in padded-jaw traps and fitted with satellite collars in Yuleba State Forest (east of Roma), Angelalla Creek catchment (between Morven and Charleville), Kumbarilla State Forest (south-west of Dalby) and in central western Queensland (Blackall area).

From location data we calculate the core areas and territory boundaries of collared individuals and use these data to calculate the distance travelled per day and the time of day when animals were active in different seasons. Daily locations detect extra-territorial movements, eventual dispersal and/or mortality if the animal is destroyed in control programs.

This research is conducted under an animal ethics permit, PAEC 051105.

Progress

The satellite tracking studies were completed in 2008 and we have analysed and interpreted all movement data.

Wild dog dispersal

Dispersal distances in 2008–09 broke all previous records. One wild dog, collared in Idalia National Park, dispersed 200 km west to a sheep property south of Stonehenge, crossing the flat and largely treeless Mitchell grass downs around Emmet within seven days. The record for largest distance travelled was for a wild dog captured near Charleville that traversed 1300 km over three months. We tracked him down on a sheep and goat property near Dunkeld, about 150 km from where he had started. However, another Charleville wild dog dispersed the furthest distance from his point of origin. This dog ended up 560 km away on Collymongel farms near Collarenebri in New South Wales. He had travelled there in 31 days.

Seasonal changes in wild dog activity

Baiting facilitates dispersal or expansion of territories and is the most likely explanation for the rapid increase in dog activity after baiting over summer. During this time, juvenile wild dogs also become independent of adult minders and there is increased pressure on packs and pack members for vacant space.

While measures of activity can show a 75% decrease between autumn and spring, the average distance individual wild dogs travel (9–21 km day^{-1}) remains the same throughout the year. However, the way wild dogs move around their territory changes (Figure 1).

It appears that males are mostly responsible for increased activity along roads and travel ways during the mating season. Females move just as much as males but their movements are less visible. They may cross roads and recognise roads as territory boundaries but they don't travel along roads. During autumn many of the females' movements are outside their territories.

After whelping and while rearing pups, males and females reduce their movement area within their territory. They frequent the most inaccessible areas; rarely use travel ways such as roads, fence lines and creek beds; and generally keep out of sight. Wild dogs seem to be intentionally avoiding areas of human activity. Most of their activity is centred on the den and the pups.

Within breeding packs there is an enormous investment of time spent in the vicinity of the den. Movement patterns of both males and females during whelping and pup rearing are characterised by a focal point (or points if the pups are moved), with brief radiating forays, presumably to catch and return prey.

Implications for wild dog management

With 15% of monitored dogs dispersing 100–560 km from their origin, the concept of controlling wild dogs in a 10–15 km buffer surrounding vulnerable livestock is not going to prevent incursions. Protecting pure dingoes in conservation areas from dispersing hybrid wild dogs or preventing dingoes from dispersing out of these conservation areas and causing livestock attacks is a difficult problem.

Seasonal movement data suggest that part of the 46% average reduction in dog activity we observe after baiting programs conducted between May and September could be just a seasonal change in their visibility and not a consequence of reduced numbers. Certainly, baiting destroys some wild dogs but it also facilitates dispersal. We must now view changes in activity following baiting, or even no apparent change, with caution. We know there is a reproductive surplus of juveniles and yearlings that are under pressure to locate a territory or either be faced with starvation or be killed by those defending their territory. From November on, juveniles, now approximately five months old, are likely to be very vulnerable to poison bait. We predict that baiting over the summer and autumn may be far more effective than during the winter and spring when adults are focused around their pups. Tracking results also suggest that repeated follow-up programs a few weeks apart are required to 'mop up' the re-colonisers who will rapidly move onto the baited area during this time.

Funding in 2008–09

Queensland Government

Desert Channels Queensland ($11 000)

Bureau of Rural Sciences ($1000)

Collaborators

South West Natural Resource Management

Desert Channels Queensland

Queensland Murray Darling Committee

DERM

More information

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

Figure 1. The hourly movements of three wild dogs during different seasons of the year in southern Queensland. A three-year-old, breeding female (white symbols and lines) visited a road (on the Northern Territory boundary) during whelping and pup rearing, but did not walk along it. In the mating season, she made numerous forays outside her territory. An adjoining yearling male (blue symbols and lines) focused his activity along the travel ways inside his territory during the mating season, but six weeks later after whelping seldom travelled on the same roads. A two-year-old female (pink symbols and lines) had not bred and was likely to be subordinate.

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

Project dates

January 2007 – June 2010

Project leader

Matt Gentle, Robert Wicks Pest Animal Research Centre
Tel: (07) 4688 1033
Email: matthew.gentle@deedi.qld.gov.au

Other staff

David Aster

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, with water provided *ad libitum*.

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, PAEC 050702.

Progress

Previously, we completed a total of seven pen trials on feral pigs using a variety of bait packages and cyanide formulations (powder, paste and liquid). Results suggest that it may be difficult to disguise the cues associated with cyanide, given its apparent distinctive smell and taste. Whether an acceptable presentation can be achieved with the current encapsulation and formulation technology is uncertain. Additionally, the inconsistent mortality of animals, even when large doses were ingested (e.g. > 50 mg kg^{-1}), suggests that feral pigs may be more resistant to cyanide than originally envisaged. Lastly, the relatively long period before unconsciousness and death in this study suggests that cyanide may not have the significant advantages to animal welfare in pigs as seen in other species (e.g. foxes). Given these difficulties, we have ceased testing any further cyanide packages on feral pigs until these issues can be overcome.

Early field trials on foxes indicated that when baits are consumed, foxes are highly susceptible to the effects of cyanide. However, despite the fact that free-feed baits were readily consumed, baits were largely rejected by foxes following the addition of cyanide. From observations gathered during the field trials, we concluded that the detectability, environmental stability and desiccation/contamination from the surrounding soil reduced the palatability and effective delivery of the cyanide paste to foxes. Odour cues were surmised to be largely responsible for foxes detecting and rejecting cyanide baits. We recommended that a greater encapsulation of cyanide, either chemically (i.e. within the carrier substrate) or physically (i.e. within an external coating), would be required to reduce the associated odour cues.

Photo 1. Fox removing bait during the field trials.

As a result, we tested a physically-encapsulated cyanide paste in an attempt to increase field acceptance and palatability. Field trials were conducted using three bait presentations. Although foxes were attracted to both non-toxic and toxic baits, the acceptance and palatability of toxic baits remained quite low. Further refinements in the presentation, palatability and delivery of these baits are needed to help mask the taste or effect of the cyanide. Desiccation of bait material remained a plausible reason why foxes were readily able to expel the cyanide baits.

Previous studies have found that initial free-feeding with non-toxic bait reduced the palatability of toxic 1080 bait. This is probably due to foxes becoming habituated to free-feed bait cues (e.g. odour, taste), and subsequently rejecting the toxic bait, which presents different cues. The magnitude of the cue differences between the free-feed and the toxic bait is likely the key; the greater the difference the more likely rejection of bait may occur.

Despite this, it is uncertain to what extent the palatability of toxic baits can be improved by reducing or abandoning free-feeding. Given the toxicity of cyanide to foxes, even a slight improvement in the palatability of the toxic bait may be enough for this technique to be successful. The results from one tested bait type are sufficiently meritorious to attempt such trials again, albeit with no or reduced free-feeding.

Funding in 2008–09

Queensland Government

Wildlife and Exotic Diseases Preparedness Program ($18 000)

Collaborators

Duncan MacMorran, Paul Aylett, Charlie Eason and Steve Boot (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 QPIF website at www.dpi.qld.gov.au

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

Project dates

January 2007 – December 2009

Project leader

Matt Gentle, Robert Wicks Pest Animal Research Centre
Tel: (07) 4688 1033
Email: matthew.gentle@deedi.qld.gov.au

Other staff

James Speed, David Aster and Annette Blair

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 using ground assessment methods. We estimate the density of damage patches through line transect techniques, and visually estimate 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 record the harvest offtake of pigs at each site. 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.

Photo 1a and 1b. Aerial surveys undertaken to measure pig density.

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

Progress

We completed four aerial surveys on all six study sites during the last 12 months. The density of feral pigs is typical for grain-producing areas, with sites having ‹ 1.5 pigs km^{-2}.

Little sorghum was planted in the 2008–09 summer cropping season; hence, few paddocks could be surveyed for damage. However, intensive ground assessments will continue to determine feral pig damage to crops (predominantly wheat) in the winter cropping season.

Photo 2. Typical feral pig damage to a wheat crop.

AQIS have supplied us with data regarding the number of wild boar exported by Australian processors (Figure 1). Although this is informative, it does not define the areas where these animals are harvested and therefore the likely effect on regulating any local populations. As a result, we are collating data from wild boar processing companies that describe the number harvested from different areas throughout Queensland.

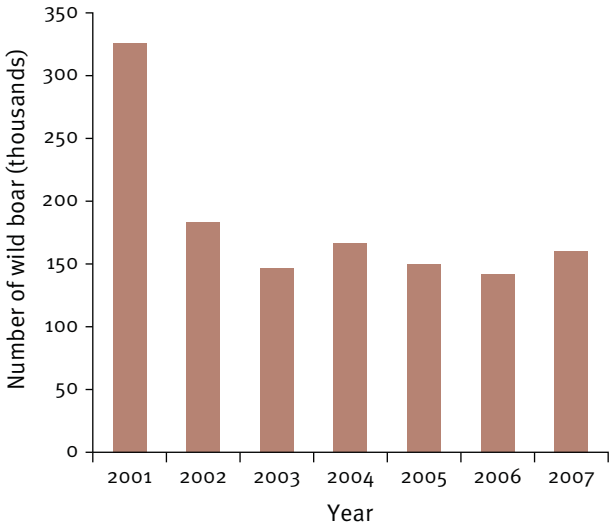

Figure 1. The number of exported wild boar from Australia, 2001–2007.

In 2008, low demand for wild boar from overseas markets has reduced demand by commercial processing companies. This, in turn, has resulted in the temporary closure of many field depots and a reduction in commercial harvester offtake. Historically, significant numbers of animals have been removed from our study sites. While we are continuing to collate harvest offtake figures, the reduction in harvester activity is likely to have significantly reduced the offtake of feral pigs from properties throughout the region, and Australia as a whole.

Funding in 2008–09

Queensland Murray Darling Committee ($174 000)

Queensland Government (Blueprint for the Bush)

Collaborators

Queensland Murray Darling Committee

Safe Food Production Queensland

AQIS

Game and meat processors

More information

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

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

Project dates

June 2007 – June 2010

Project leader

Jim Mitchell, Tropical Weeds Research Centre
Tel: (07) 4761 5734
Email: jim.mitchell@deedi.qld.gov.au

Other staff

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

All fencing is complete and has remained pig-proof for two years. Sampling commenced in August 2007. All of the lagoons were sampled twice in 2007, three times in 2008 and twice in 2009 to date. The Australian Centre for Tropical Freshwater Research (James Cook University) has entered into an agreement to conduct this component of the project.

Water clarity was strongly affected by pig foraging activity in the unfenced lagoons. Unfenced lakes developed significantly lower secchi depths and higher turbidity. Pig-proof fencing made no significant difference to levels of nutrient enrichment in the lakes in terms of total nitrogen, total dissolved nitrogen, ammonia, total phosphorus or total dissolved phosphorus. The temporal destruction of wetland vegetation by feral pigs in the unfenced lakes resulted in a significant biological oxygen demand within them, with fenced lakes having significantly higher dissolved oxygen levels during both day and night. Dissolved oxygen saturation followed the same trend, becoming significantly lower in the unfenced lakes during both day and night. The anaerobic conditions that resulted from the destruction and subsequent decomposition of wetland vegetation in the unfenced lakes also caused a significantly lower pH to develop in these habitats.

Aerial shooting around the lakes has destroyed over 1000 pigs to date. A weak relationship between increasing pig population levels and increasing turbidity has been demonstrated. Population monitoring and water sampling of the lakes is continuing.

Funding in 2008–09

Queensland Government

DEWHA ($28 000)

Collaborators

James Cook University, Australian Centre for Tropical Freshwater Research

DERM

More information

Key publications

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* (online early).

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

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

Project dates

January 2007 – December 2009

Project leader

James Speed, Robert Wicks Pest Animal Research Centre
Tel: (07) 4688 1213
Email: james.speed@deedi.qld.gov.au

Other staff

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.

Feral cats and foxes are trapped, fitted with GPS radio collars and conventional 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 if these pathways overlap with the monitoring program.

Following trapping, we measure a number of indices of animal activity, 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 over three days. We also install 30 remote cameras throughout the site for one-month periods.

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 the mortality of collared feral cats and foxes. 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

To date, we have completed six rounds of spotlighting covering approximately 720 km and yielding 22 cats and 96 foxes. We have monitored passive plots over five monitoring periods (139 sets of fox tracks and 14 sets of cat tracks) along with two months of remote camera monitoring.

Trapping resulted in a final tally of 10 cats and 15 foxes. GPS collars were retrieved from three cats. Numerous ground-based locations were recorded for several other cats and foxes with conventional radio collars.

We conducted evaluation of broadscale shooting over 11 nights at the Crowders Creek site. During this time 48 foxes and 20 cats were shot. DNA samples and stomachs were collected from each animal for future analysis.

Funding in 2008–09

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 QPIF website at www.dpi.qld.gov.au

6. Adaptive management of rabbits (*Oryctolagus cuniculus*)

Project dates

2000–2012

Project leader

David Berman, Robert Wicks Pest Animal Research Centre
Tel: (07) 4688 1294
Email: david.berman@deedi.qld.gov.au

Other staff

Michael Brennan and Peter Elsworth

Objectives

Establish landholder-driven, scientifically monitored rabbit control programs at Bulloo Downs and in the Darling Downs–Moreton Rabbit Board (DDMRB) area to:

- demonstrate the importance of targeting control activities in key breeding places (sources)
- measure the cost of eradication of small, isolated rabbit populations
- measure the benefits of rabbit control to biodiversity, agriculture and pastoralism.

Rationale

Bulloo Downs in south-western Queensland has probably been the main source of rabbits (*Oryctolagus cuniculus*) that recolonised much of the region after droughts. Attempts to control rabbits over the past 100 years have all been relatively unsuccessful. Rabbits continued to infest Bulloo Downs even after RHDV had effectively reduced rabbit populations to very low levels in most other arid parts of Australia. With this apparent failure of biological control, we established a scientifically monitored, landholder-driven rabbit control program in 2001 to measure the cost and effectiveness of warren ripping. Such programs are an excellent way to encourage rabbit control by demonstrating the best available control techniques, the benefits of controlling rabbits and the dangers of doing nothing. If proven cost-effective, identification and treatment of drought refuge areas similar to Bulloo Downs may relieve a large area of arid Australia from the damage caused by rabbits. Monitoring is required to determine the long-term effectiveness of this strategic rabbit control.

In south-east 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 and yet it 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 in south-east Queensland, using techniques similar to those used at Bulloo Downs. 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' may have the potential to minimise the cost of rabbit control and maximise its long-term effectiveness in south-east Queensland as well.

Methods

Bulloo Downs

Between 2002 and 2004, 55 000 warrens were ripped on Bulloo Downs in areas considered to be drought refuges for rabbits. We conduct surveys of warren activity and spotlight counts annually to measure the long-term success of the rabbit control program at Bulloo Downs. To help measure the influence of rabbit control and separate it from other factors, we also conduct counts at Coongie Lakes in South Australia, where there has been no rabbit control. The Coongie Lakes area is similar to Bulloo Downs with regard to its suitability for rabbits and is an important drought refuge for rabbits.

Darling Downs–Moreton Rabbit Board area

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 DDMRB 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. The site is ideal for measuring the differences in pasture and biodiversity caused by rabbits. 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, and further distribute sand plots to count rabbit tracks and predator tracks throughout the site. 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

Bulloo Downs

Over the last eight years, Bulloo Downs has had seven years of below average rainfall. A comparison of rabbit numbers at Bulloo Downs and those at Coongie Lakes (Figure 1) indicated that the strategic ripping of warrens in drought refuges at Bulloo Downs caused at least a 99% reduction in rabbit numbers. Coongie Lakes has had no ripping and has maintained relatively high rabbit numbers (16.5 rabbits km^{-1}, SE ±5.06), while rabbit numbers at Bulloo Downs have been extremely low (0.1 rabbits km^{-1}, SE ±0.06), most likely because the drought refuge was ripped.

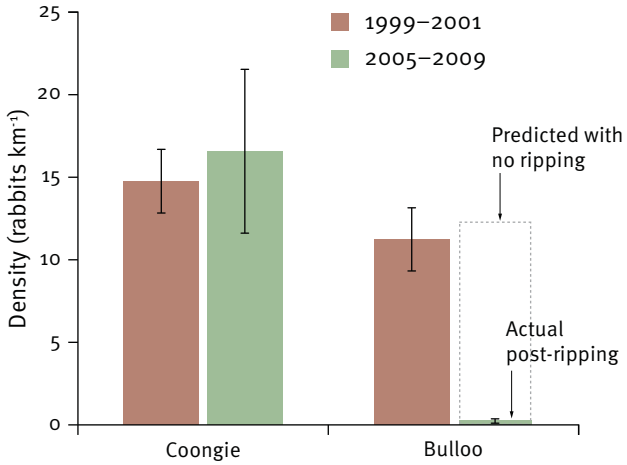

Figure 1. Rabbit density between 2005 and 2009 at Bulloo Downs was at least 99% less than predicted based on counts from Coongie Lakes. (Vertical bars indicate the SE of the means.)

Following one good rainfall year in 2007, rabbits have not recovered on Bulloo Downs, where the drought refuge was treated properly by ripping. However, they appear to be recovering and spreading back out from one drought refuge area (Jerridah waterhole) where too few warrens were ripped. This site was not previously recognised as a drought refuge area.

The area around Jerridah Waterhole saw an increase in rabbit numbers from below 10 000 to around 200 000 (approximately 20 rabbits km^{-1}) by October 2008. Although this is a disturbing amount, it is small compared to a scenario without any warren ripping (Figure 2). If rabbits had been able to use all the drought refuge, they could have recovered to a population of 700 000 in only four years. Dry conditions in 2008 and 2009 appear to have forced rabbits back towards the Jerridah drought refuge area. There is an urgent need to complete the destruction of the drought refuge of rabbits on Bulloo Downs. Ripping all warrens within a 10 km radius from Jerridah waterhole will remove the source of recolonisation and leave just low density, isolated populations that are vulnerable to predators and drought. It is vitally important to act as soon as possible before rabbits spread back across all suitable habitat on Bulloo Downs and the wider region.

By focusing on destroying warrens in the areas where rabbits survived droughts, we have achieved a significant reduction in numbers. This has reduced the overall cost of control by millions of dollars and reduced the damage caused to biodiversity and cattle production. Low rabbit numbers have allowed cattle to continue to be run on the property even though the area has experienced the most severe lack of rainfall on record.

Darling Downs–Moreton Rabbit Board area

Measurements are currently underway inside and outside the rabbit-proof fence. The absence of warrens from the 'clean side' shows that the fence is effective in preventing rabbits from establishing warren systems. Preliminary results indicate that the 'dirty side' is characterised by a high number of warrens, a high density of rabbits, fewer pasture species and low macropod activity (Figure 3).

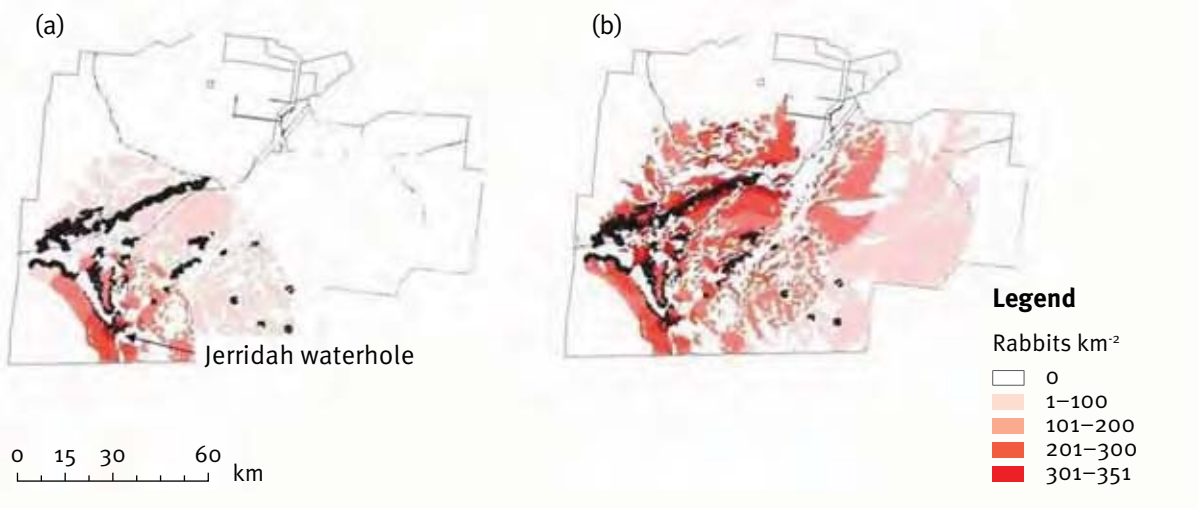

Figure 2. Ripped warrens (black) and distribution of rabbits a) in September 2008 and b) potential distribution if warrens had not been ripped and rabbits had spread out from all drought refuge.

Warrens have been ripped and rabbit numbers reduced by 60% on the 'dirty side' of the fence. The remaining rabbits are in areas where warrens have not yet been ripped. Once warren-ripping is complete, rabbit numbers should be very low on both sides of the fence. If rabbits have been the cause of differences in macropod activity, then macropod activity should increase on the 'dirty side' of the fence. Likewise, if the difference in pasture composition has been caused by rabbits, then this difference should decline on the 'dirty side' of the fence.

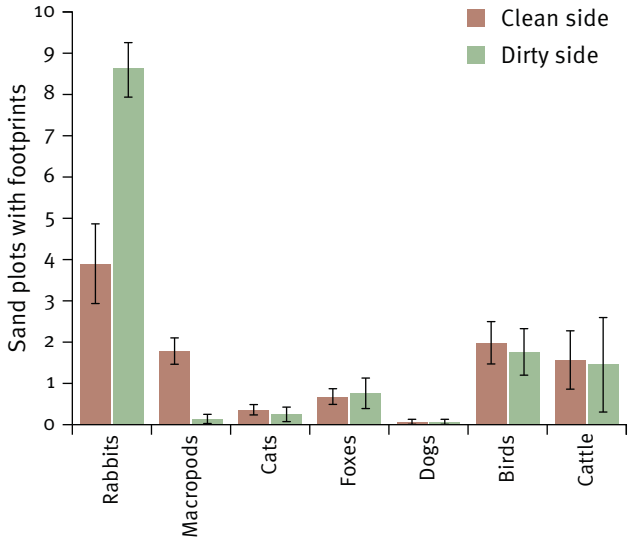

Figure 3. Tracks recorded on sand plots on the 'dirty side' and the 'clean side' of the rabbit proof fence. Rabbits have much higher activity on the 'dirty side' and macropods have high activity where rabbit activity is low. (Vertical bars indicate the SE of the means.)

Funding in 2008–09

Land Protection Fund

Queensland Government

Collaborators

Mark Ridge (DDMRB)

More information

Key publications

Berman, D. 2008. Control of rabbits in arid Australia: destroying the drought refuge. 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. 153.

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.

Berman, D., Kerr, P.J., Stagg, R., Van Leeuwen, B.H. and Gonzalez, T. 2006. Should the 40-year-old practice of releasing virulent myxoma virus to control rabbits (*Oryctolagus cuniculus*) be continued? *Wildlife Research* 33(7): 549–556.

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.

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 QPIF website at www.dpi.qld.gov.au

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

Project dates

July 2008 – July 2010

Project leader

David Berman, Robert Wicks Pest Animal Research Centre
Tel: (07) 4688 1294
Email: david.berman@deedi.qld.gov.au

Other staff

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 became viewed as Australia's most serious vertebrate pest. During the past sixty 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 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 availability 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 records of rabbit occurrence and rabbit density. We also look for associations between rabbit occurrence and soil type, temperature, rainfall, tree cover, rabbit control and other factors that may determine rabbit distribution and abundance. These associations may be used to extrapolate distribution and abundance to areas where there are not enough records. On the basis of collected data, we produce an improved map of the distribution and abundance of rabbits in Australia.

Progress

From published and unpublished sources we have obtained coordinates for 2784 points where rabbits are known to have been living prior to Rabbitscan. Rabbitscan respondents reported rabbit density at 2575 sites during May–June 2009 (Figure 1).

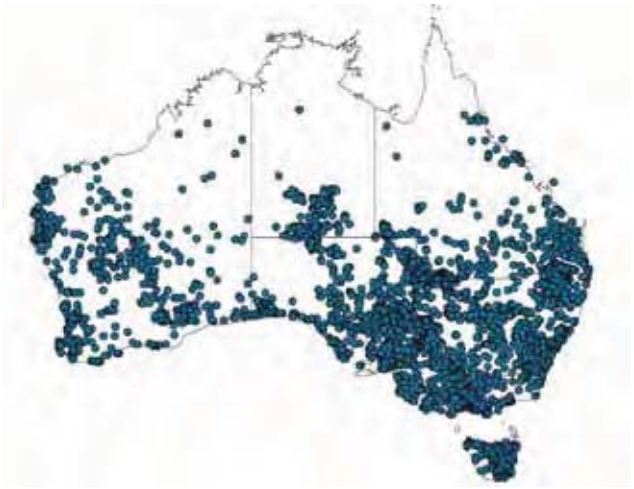

Figure 1. Sites (blue dots) where rabbits have been reported, including Rabbitscan sites, for May 2009.

The DDMRB fence and rabbit control activities have prevented rabbits from establishing in a large part of south-east Queensland. Rabbitscan data clearly show the recent invasion of rabbits into the previously rabbit-free area to the north of the DDMRB area (Figure 2). This movement of rabbits from the north is a severe threat to the DDMRB area. An increased rabbit control effort is required to prevent further invasion.

It is important to note that in most cases rabbits have not yet established complex warren systems within the new areas of infestation and therefore will not have reached their potential maximum densities. However, rabbits cause significant damage to horticulture and the environment even at low densities. Once complex warren systems are established, rabbits can reach very high densities and cause significant damage to the economy and perhaps irreparable damage to the environment.

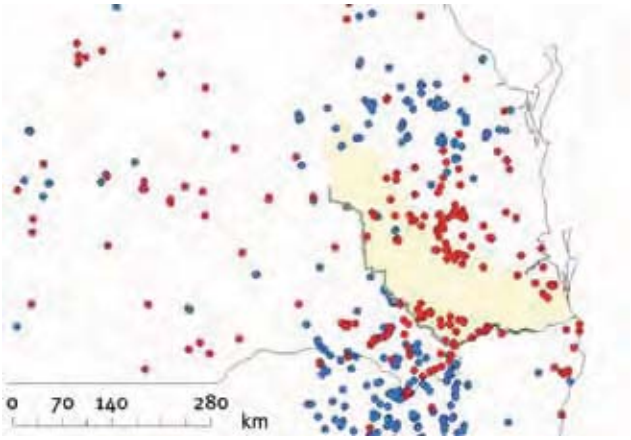

Figure 2. Sites where rabbits were reported prior to Rabbitscan (blue dots) and via Rabbitscan for May 2009 (red dots) in south-east Queensland. DDMRB area (shaded in yellow) and rabbit-proof fence (grey line) are also shown.

This work highlights the importance of mapping the distribution and abundance of rabbits for identifying areas that require an increase in control effort. If continued, Rabbitscan could provide a means to measure the effectiveness of increased control efforts.

Funding in 2008–09

Land Protection Fund

Queensland Government

Collaborators

Rabbit Management Advisory Group

Brian Cooke (Invasive Animals CRC; University of Canberra)

Damien Fordham (The University of Adelaide)

Grant Hamilton (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 QPIF website at www.dpi.qld.gov.au

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

Project dates

July 2007 – June 2010

Project leader

Peter Elsworth, Robert Wicks Pest Animal Research Centre
Tel: (07) 4652 1599
Email: peter.elsworth@deedi.qld.gov.au

Other staff

David Berman, David Aster and Robert Thomson

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

Rabbit haemorrhagic disease (RHD) 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. Concerns have been raised about RHD'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 12 years 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 RHD 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-RHD, they would once again have a devastating effect. An understanding of the current interactions between rabbits and RHDV will provide a way forward for control of rabbits with RHDV or highlight the need for alternative, additional management tools.

Methods

We infect domestic rabbits with RCV-A1, a strain of rabbit calicivirus thought to be non-virulent. Non-infected domestic rabbits are exposed to the infected rabbits and four weeks are allowed for infection to spread. We then

directly challenge half of the total number of rabbits with RHDV, and allow the other half contact with those rabbits to gain the disease by spread. We take blood samples and swabs, and measure body weight and temperature periodically to establish stage of infection and disease. Full necropsies are performed upon death or the end of trial.

Photo 1. Domestic rabbits challenged with benign RCV-A1 to assess its interactions with RHDV.

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) is currently performing a phylogenetic analysis to establish how much the virus may have changed over time. Virus is standardised using ELISA titration and real-time RT-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.

Progress

Trials showed that infection with RCV-A1 does not result in a lethal disease. All rabbits survived with little to no impact on health. This confirmed that RCV-A1 is a benign virus to rabbits. Subsequent challenge with RHDV, either directly or by contact with infected rabbits, resulted in 86% mortality (n=46). Therefore, the presence of antibodies to RCV-A1 does not appear to infer immunity to RHDV. There was, however, a delayed mortality (167 hours post-infection) compared to that normally seen in RHDV challenge trials (80 hours post-infection).

We have obtained field strains of RHDV from Turretfield for the last three years for virulence testing. A standard line of wild rabbits has been bred from rabbits trapped at Turretfield. A test protocol has been developed and trials will be run by the end of 2009.

Funding in 2008–09

Queensland Government

Collaborators

Brian Cooke (Invasive Animals CRC)

Steve McPhee (Department of Primary Industries, Victoria)

Greg Mutze, Ron Sinclair and John Kovalivski (Department of Water, Land and Biodiversity Conservation, South Australia)

Tanja Strive and John Wright (CSIRO)

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 QPIF website at www.dpi.qld.gov.au

9. Effective and safe rodent management

Project dates

April 2006 – December 2009

Project leader

Peter Cremasco (until September 2008); Tony Pople (from September 2008), Robert Wicks Pest Animal Research Centre
Tel: (07) 3375 0728
Email: tony.pople@deedi.qld.gov.au

Other staff

David Aster, Bob Parker, Julianne Farrell, Joe Scanlan and 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.
- Refine best practice strategies for control of mice (*Mus domesticus*) on Queensland grain farms.
- Provide management guidelines for canefield rats (*Rattus sordidus*) in central Queensland.

Rationale

Rats and mice cause annual losses of about $30 million to Australian grain producers. At the start of this project, grain producers were concerned that there was only a single rodenticide, zinc phosphide (presented as a coating on wheat grains in the product MOUSEOFF® ZP), registered for broadacre use and supplied by a single manufacturer. A similar bait (Surefire® Zinc Phosphide Mouse Bait) is now produced by a second manufacturer. This was considered a risk, as regulators may place restrictions on the rodenticide's use because it is a hazard to children and pets, it may become less effective (e.g. through bait aversion) and the manufacturers may be unable to maintain supply.

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. Glasshouse testing showed no residues on crops exposed to bromethalin or zinc phosphide baits. Cholecalciferol was more promising than bromethalin as it is less toxic to birds and is currently registered for use in bait stations in Australia (around buildings) and New Zealand. These trials now need to be extended to the field to demonstrate the ability of these rodenticides to control mice.

Mouse plagues occur on average every three to four years in Queensland. Models predicting plagues from rainfall enable growers to plan future management to reduce crop losses. Bait manufacturers also require sufficient lead time to supply enough bait to suppress developing plagues.

Factors other than rainfall influence the density of mice on a property, including vegetation composition around crops, timing of cropping and obviously baiting for mice. These can be manipulated, but it is unclear which approach provides the optimum and most cost-effective control of mice.

Methods

Rodenticide trials

Field testing is not possible because APVMA would not provide a permit. An alternative is to undertake the trial in a crop grown in a large enclosure. This has the advantage that known densities of mice can be released and then baited. Predators and movement of mice can also be controlled. Safety of these rodenticides also needs to be assessed by monitoring possible impacts on other species such as native birds and mammals, again ideally in the field.

Trials of the efficacy of cholecalciferol are undertaken in field enclosures at UQ, Gatton. Industry partners (Connovation Ltd, Bell Laboratories and Animal Control Technologies Australia) are providing baits. These include a lower dose of cholecalciferol and one that combines low doses of cholecalciferol with coumatetralyl, which act synergistically. Both these formulations potentially avoid bait shyness that may occur with the higher dose of cholecalciferol. We compare the efficacy of these baits with a currently registered zinc phosphide bait (MOUSEOFF® ZP) and unbaited control plots. Ideally, the efficacy of a pesticide should be assessed on its ability to reduce damage rather than simply reduce numbers of a pest. To this end, we determine actual yield loss caused by mice by comparing wheat yield in mouse exclusion plots within each pen with yield in plots exposed to mouse damage.

Modelling

Regular trapping of mice has been undertaken since 1974 at the same 47 sites in southern Queensland. This has provided an index of abundance over time that can be related to rainfall. Rainfall is a useful indicator of density about half the time, but of plagues in many cases. This model can hopefully be improved with a longer time series. We trap mice along transects at two sets of 20 sites elsewhere on the Darling Downs and 46 sites in central Queensland over five years. These data are analysed together with historical data to assess existing models and develop new models predicting mouse numbers.

Coupled with data on management practices and vegetation, these data can be analysed to determine best management practices for mouse control. Trapping in central Queensland is also aimed at providing information on the biology and population dynamics of the canefield rat.

Progress

Rodenticide trials

In 2008, Bell Laboratories submitted a registration package for the zinc phosphide pellet (ZP Mouse), so field trials for this bait were not required. For the field enclosure trials at Gatton, a wheat crop was sown in winter 2009 in a series of pens within the outdoor enclosure and mice will be introduced to pens in varying densities just prior to harvest in late 2009.

Modelling

Trapping of mice continued until December 2008 on the Darling Downs and in central Queensland, although there were few captures in central Queensland.

We have recorded management practices in crops and habitat data until December 2008 for an assessment of best practice management for mice in grain crops. During the study, there have been no captures of the canefield rat in central Queensland.

Funding in 2008–09

Queensland Government

Collaborators

Bell Laboratories Inc.

Animal Control Technologies Australia

Connovation Ltd, New Zealand

Grain farmers

Luke Leung (UQ—through UniQuest)

More information

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

10. Controlling feral goat (*Capra hircus*) populations through commercial harvesting

Project dates

January 2008 – December 2009

Project leader

Tony Pople, Robert Wicks Pest Animal Research Centre
Tel: (07) 3375 0728
Email: tony.pople@deedi.qld.gov.au

Other staff

Moya Calvert

Objectives

- Describe the distribution and abundance of feral goats in the sheep rangelands of Queensland since 1980.
- Determine the commercial harvest rate of goats over the survey period.

Rationale

While feral goats (*Capra hircus*) can be successfully controlled at a property scale, broadscale control has not happened despite a long history of commercial use in Australia. Feral goat populations have been monitored in the sheep rangelands on aerial surveys for kangaroos since the 1970s, providing an indication of population trend under harvesting. A three to four–fold rise in the value of feral goats in the mid 1990s was thought to be a catalyst for a substantial reduction in Australia's feral goat population.

Harvesting will obviously reduce the size of pest animal populations, but not necessarily to levels where pest impact is acceptable and not in areas where reductions are most required. Reduction by harvesting, while efficient, may well be suboptimal. More effective control may be achieved by supplementing the commercial harvest in some way (e.g. industry development, subsidies) or using alternative methods of control even if it means compromising the commercial harvest.

Methods

Goats were counted on fixed-wing aerial surveys for kangaroos annually during 1984–1992 and in 2001, across an area of 500 000 km^2 of the sheep rangelands in semi-arid Queensland where dingoes are controlled. Double count methods (a form of mark-recapture) were used on some surveys, allowing correction factors to be developed to adjust counts for visibility bias. Since 1991, these surveys have been undertaken by helicopters in 5–19 survey blocks and goats have also been counted. Line transect methods are used to correct for visibility bias.

We collate harvest data from Australian Bureau of Statistics (ABS) figures for 2005–06 as well as published

records of AQIS inspections at abattoirs and a smaller number of goat life exports. We assume that 70% of goats slaughtered for export and 90% of live exports were of feral origin. Abattoir data are broken down by state, but do not necessarily identify the source of goats as they may have been transported from interstate. These data are then used to generate estimates of harvest rate for Queensland. ABS data are broken down regionally, allowing an assessment of spatial variation in harvest effort and rate. Simple harvest models are used to suggest the likely population reductions achieved from harvesting.

We determine trends in feral goat distribution by calculating the slope of the regression of logged density over time for 50 km × 50 km grid squares across the survey area. This generates a map of the exponential rate of increase for goats during 1984–2001.

Progress

Over the past 20 years approximately 100 000–300 000 feral goats have been removed from Queensland annually, representing 30–60% of the national offtake since 1998. Despite the price increase, harvesting in Queensland has not driven populations to relatively low densities. Feral goat numbers in Queensland appear to have increased from around 100 000 in the mid 1980s to over one million animals by 2001 (Figure 1). A decline in the mid 1990s is likely to be the result of drought, as numbers recovered on the back of good rainfall in the latter part of the decade. This inability to reduce goat numbers substantially through harvesting is likely to result from a combination of high rates of increase in good seasons, availability of refuges from harvesting and an inability to maintain a high rate of harvest over an extensive period.

Limited data on harvesting suggest the harvest rate was around 30% in the early 1990s but around 20% in 2005 (Figure 2). If harvest rates of 20–30% were maintained, they should achieve a long-term reduction in average population size of 40–50%.

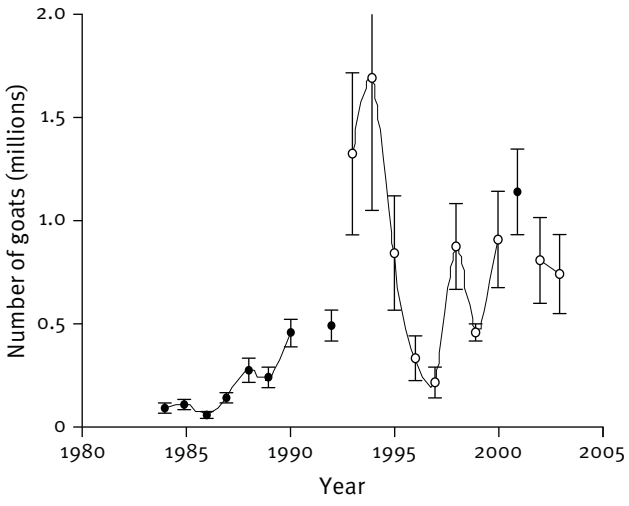

Figure 1. Fluctuations in the population of feral goats in central and southern Queensland as determined by fixed-wing aerial surveys (solid circles) and helicopter surveys (open circles). (Vertical bars indicate the SE of the means.)

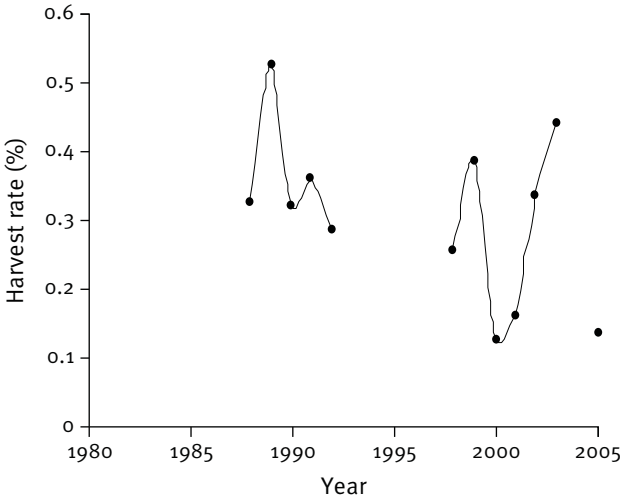

Figure 2. Harvest rate of feral goats in the Queensland survey area.

There is no obvious spatial pattern in the trend in feral goat numbers in Queensland, with increases across their distribution (Figure 3). Harvest rate is uneven across this distribution (Figure 4), but cannot readily explain any variation in trend.

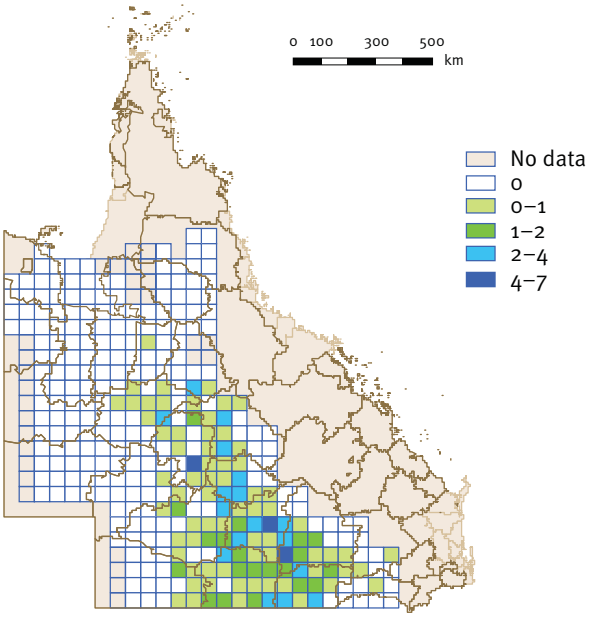

Figure 3. Average density (goats km^{-2}) of feral goats in a 50 km × 50 km grid based on aerial surveys undertaken in 1984–2001. The surveys only extended into far western and northern Queensland in 1984.

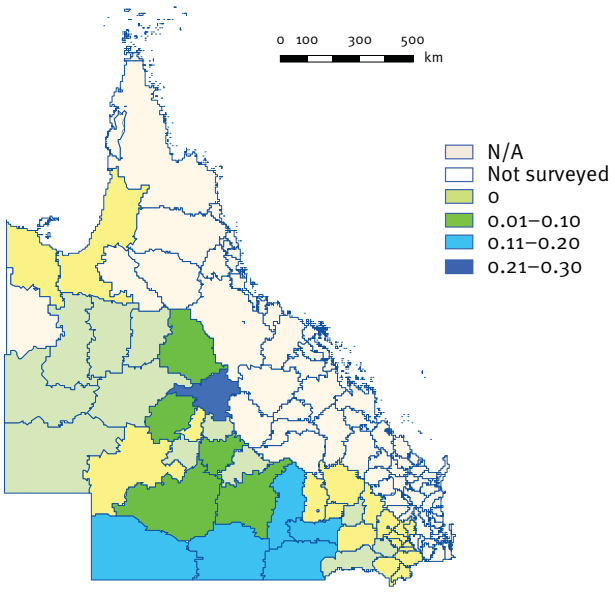

Figure 4. Harvest rate of feral goats in local government areas using harvest offtake in 2005–06 and density estimates for 2001.

Funding in 2008–09

Queensland Government

Collaborators

Geoff Lundie-Jenkins (DERM)

More information

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

11. Modelling options for management of feral camels (*Camelus dromedarius*) in central Australia

Project dates

January 2008 – December 2009

Project leader

Tony Pople, Robert Wicks Pest Animal Research Centre
Tel: (07) 3375 0728
Email: tony.pople@deedi.qld.gov.au

Objectives

- Reassess the growth of the Northern Territory camel population using published population estimates and life history data to quantify the amount of control required to suppress growth through harvesting, culling or fertility control.
- Determine environmental predictors of camel distribution in the Northern Territory.
- Identify areas in the Northern Territory where commercial harvesting is feasible and the resultant potential reduction in densities.

Rationale

Since their release over 100 years ago, camels (*Camelus dromedarius*) have spread across central Australia and increased in numbers. Irregular aerial surveys since 1983 and an interview-based survey in 1966 suggest that camels have been increasing at close to their maximum potential rate. While they already have observable impacts from overgrazing and damage to infrastructure such as fences, wild camels are not currently seen as a major pest. There is thus a call for present action to alleviate future costs. Target densities of 0.1–0.2 camel km^{-2} have been recommended.

The three main options for control of camels are:

- exclusion fencing
- commercial harvesting, including capture and domestication by landholders
- ground-based and aerial culling.

Fertility control is a further option, but a species-specific method would need to be developed, as would its broadscale delivery.

The effectiveness of control through harvesting or culling, which has been successful in reducing feral horse and donkey numbers, is compromised by a number of factors. Compared to horses and donkeys, camels form smaller herds and visit water points less frequently. The spatially variable and generally low density of camels, combined with a punctuated, presently unpredictable pattern of ranging over large areas, makes harvesting difficult and costly. Modelling can be used to quantify the control required to manage the impacts of camels and to identify preferred habitats and areas of high abundance to help focus control efforts.

This study is relevant to Queensland, as the current edge of the range of camels is Queensland's western border and their containment will depend on effective control in central Australia. Further, identifying habitat associations in the Northern Territory will help determine likely areas for invasion in Queensland. There is also interest in developing a domestic camel industry in Queensland and building that population from feral herds.

Methods

Demography

Three population models are fitted to estimates of density (with their associated observation errors) and include two forms of density dependence. We use a stage-structured model based on life history data from a central Australian camel population to explore the effects of varying age-specific estimates of survival (e.g. culling) and fecundity (e.g. fertility control) on the resulting estimates of rate of increase (=elasticity).

Habitat modelling

Locations and numbers of camels were recorded in 2001 in an aerial survey of the southern Northern Territory, sampling 3.6% of an area of 260 000 km^2.

We model habitat associations in two steps. Firstly, the 'presence-only' data are supplemented by an equivalent number of 'pseudo-absence' sites (i.e. randomly selected sites where camels were not observed). These data are then related to a range of biotic and abiotic habitat covariates using logistic generalised additive models. We calculate habitat covariates for buffers of 1 km and 5 km around sites. Secondly, we use Poisson generalised additive models to relate camel abundance to habitat covariates, conditional on camels being present. We then calculate predicted abundance from the product of the two models.

The costs of harvesting (e.g. searching, handling, transport) and the value of harvested animals could help determine which areas are likely to be suitable for commercial harvesting. As such data are not available, a detailed analysis of commercial harvesting is not possible. However, an indication of suitable areas can be gained by placing ever-increasing buffers around the road network and comparing these with the 2001 and predicted density distributions for camels.

Progress

Demography

A comparison of three models of population growth fitted to these albeit limited data suggests that the Northern Territory population has indeed been growing exponentially at an annual rate of r = 0.074, or 8% per year, with little evidence of a density-dependent brake. The interview-based estimate of numbers in 1966 was likely to have been an underestimate. A stage-structured model suggests that this rate approximates the theoretical maximum. Elasticity analysis indicates that adult survival is by far the major influence on rate of increase and that a 9% reduction in survival from 96% is needed to stop the population growing. This is no small feat, requiring a tripling of the natural mortality rate. In contrast, at least 70% of mature females need to be sterilised to have a similar effect (Figure 1).

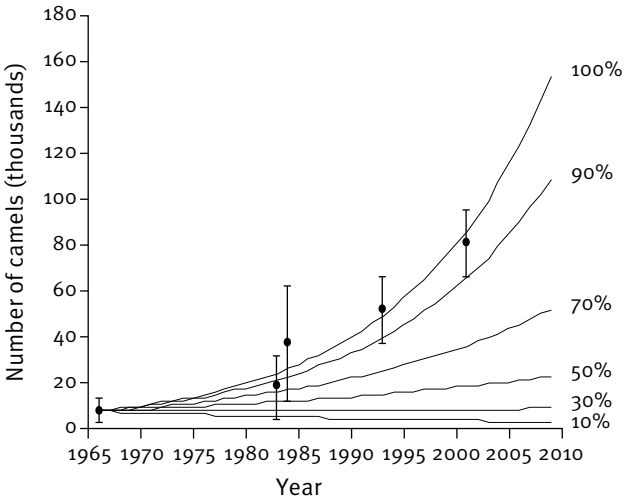

Figure 1. Trajectory of camel populations subjected to a range of fertility control programs that sterilise up to 90% of reproductive females. Estimates (± 95% confidence interval) of camel population size in the Northern Territory are shown as solid circles.

Theory and some empirical evidence predict that a large mammal population will increase almost exponentially until close to carrying capacity, supporting what has been observed in central Australian camels. This will frustrate control programs, because an ever-increasing number of animals will need to be removed for zero growth, the longer that culling or harvesting effort is delayed. A population projection for 2008 suggests about 10 500 animals need to be harvested across the Northern Territory to stop population growth. Current harvests fall well short of this.

The ability of commercial harvesting to control camel populations in central Australia will depend on the value of animals, access to animals and the presence of alternative species to harvest when camels are at low density. The ability of harvesting to hold a population at a particular density will depend on the productivity of the population and how offtake rate changes in response to changes in the density of the harvested species. The growth (or productivity) of the population at various densities is known as a yield curve, indicating the sustained harvest that can be taken from the modelled population while holding it at a constant density (i.e. r = 0) below carrying capacity (Figure 2). Two hypothetical offtake curves are also shown and reach an asymptote as there will be an upper limit to supply dictated by market availability and processing infrastructure.

Conversely, at low densities, animals are difficult to find or it is simply not worth harvesting because of small returns. Where the lines intersect is the new equilibrium density. If the value of camels increases, offtake should also increase, all else being equal. There would then be the potential to suppress camel numbers to a low density. However, as shown in Figure 2, above some moderate

density, the population could still escape this 'predator pit' and continue to grow to an equilibrium density just short of carrying capacity. A final scenario is where harvesters have good access to camels and can continue to operate because they have alternative and more abundant species (e.g. feral horses, donkeys and domestic cattle) to harvest. In this case it may be economical to harvest and maintain camels at low density.

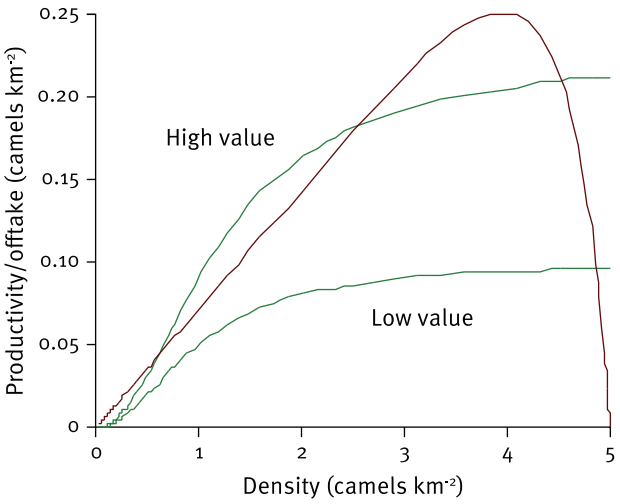

Figure 2. Productivity curve (brown line) for a camel population and two sigmoidal offtake curves (green lines).

Habitat modelling

While a major part of the southern Northern Territory was predicted to be suitable habitat for camels, modelling suggests that most of this area supports only low densities, with occasional high density 'hotspots'. These hotspots were associated with a wide range of vegetation communities. Notably, while the Queensland border contained suitable habitat, there were no hotspots. An important caveat is that camels are unlikely to be near carrying capacity and so their habitat associations may change over time, although their current range encompasses the area over which predictions were made. Furthermore, the data represent only a snapshot of their associations with habitat.

There are large regions in the south-west and west of the southern Northern Territory that do not contain major or minor roads. These regions also coincide with predictions of high densities of camels, suggesting commercial harvest operations here will be hampered.

Funding in 2008–09

Desert Knowledge CRC, via Department of Primary Industries, New South Wales ($31 000)

Collaborators

Desert Knowledge CRC

Steve McLeod (Department of Primary Industries, New South Wales)

Keith Saalfeld and Glenn Edwards (Natural Resources, Environment, The Arts and Sport, Northern Territory)

More information

Key publications

McLeod, S.R. and Pople, A.R. 2008. *Modelling management options for management of feral camels in central Australia*. Desert Knowledge CRC Research Report 48. Desert Knowledge CRC, Alice Springs.

For further information on this research project and access to key publications, visit the invasive plant and animal science pages on the QPIF website at www.dpi.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

Project leader

Bill Dorney, Tropical Weeds Research Centre
Tel: (07) 4064 1149
Email: william.dorney@deedi.qld.gov.au

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. 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 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 feral deer 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 sign transects, remotely triggered trail cameras and landholder surveys. Once a suitable population is found, testing of appropriate control options commences. Trapping (such as 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

The trial is now in the final phase. It initially proved difficult to find a field site with sufficient deer to test control options, though monitoring methodologies were extensively trialled. Eventually, we found a suitable small population near Kuranda where we assess the feasibility of trapping. Rusa deer at the site are readily feeding on grain laid at bait stations monitored with remotely triggered cameras (Photo 1).

Photo 1. Rusa deer feeding on grain.

We have also built a modified version of the Clover trap, based on information from the Minnesota Department of Natural Resources. To date we have been successful in capturing two deer from a small herd in this trap (Photo 2). The remainder of the deer have continued to stay in the area and we now focus on whether multiple captures over time are possible. Other potential control options will also be incorporated in an attempt to capture complete herds.

Photo 2. Deer captured using a Clover trap.

Funding in 2008–09

Queensland Government

Wet Tropics Management Authority, Terrain Natural Resource Management ($3000)

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 QPIF website at www.dpi.qld.gov.au

Part 4 Research services

1. Pest management chemistry

Project dates

Ongoing

Project leader

Bob Parker (until October 2008); Lesley Ruddle (from October 2008), Alan Fletcher Research Station
Tel: (07) 33750746
Email: lesley.ruddle@deedi.qld.gov.au

Other staff

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 eco-toxicological investigations relating to the use of vertebrate pesticides. We maintain a laboratory and formulation facility at AFRS and also 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 analysis methods for a range of vertebrate pesticide and herbicide formulations.

Progress

Forensic toxicology

We have added dicoumarin, a naturally occurring anticoagulant, to the laboratory's profile of tests. Dicoumarin is found in spoiled sweet clover and can be a cause of poisoning in cattle if sweet clover is present in cattle silage and hay.

Over the year, our laboratory performed 74 investigations relating to possible fluoroacetate poisoning, 39 relating to possible strychnine poisoning, 29 relating to possible anticoagulant poisoning, 1 relating to possible metaldehyde poisoning and 7 relating to possible dicoumarin poisoning. Most investigations related to domestic dogs and cats; however, there were some also 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 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 2008–09

Land Protection Fund

Queensland Government

2. Chemical registration: providing tools for invasive pest control

Project dates

Ongoing

Project leader

Bob Parker (until October 2008); Karen Boundy (from October 2008), Alan Fletcher Research Station
Tel: (07) 3375 0736
Email: karen.boundy@deedi.qld.gov.au

Other staff

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

During the past year the following permits were renewed or obtained:

- permit for the use of Weedmaster® Duo Herbicide and other registered products containing 360 g L^{-1} glyphosate for the control of salvinia
- permit renewal for the use of Dupont Ally® Herbicide and other registered products containing 600 g L^{-1} metsulfuron methyl for the control of parthenium weed
- permit renewal for the use of 360 g L^{-1} glyphosate and 500 g L^{-1} dicamba herbicide products for the control of cat's claw creeper
- permit renewal for the use of 225 g L^{-1} & 500 g L^{-1} 2,4-D amine, 450 g L^{-1} glyphosate and 600 g L^{-1} metsulfuron methyl herbicide products for the control of lippia
- permit renewal for the use of Curiosity® 1080 Cat Bait for the control of feral cats
- renewal with amendments for the Environmental Weeds Permit; the amendment included the addition of HotShot*, Arsenal® Xpress and Starane Advanced*
- permit renewal for the use of Arsenal® Xpress Herbicide and other registered products containing 150 g L^{-1} glyphosate and 150 g L^{-1} imazapyr for the control of *Thunbergia* spp.
- permit for the use of Roundup Biactive® Herbicide containing 360 g L^{-1} glyphosate for the control of water hyacinth at Horse Creek, South West Queensland.

Funding in 2008–09

Land Protection Fund

Queensland Government

Appendixes

1. Abbreviations

ABS	Australian Bureau of Statistics
ACIAR	Australian Centre for International Agricultural Research
AFRI	Arid Forest Research Institute, India
AFRS	Alan Fletcher Research Station
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
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
DDMRB	Darling Downs–Moreton Rabbit Board
DERM	Department of Environment and Resource Management, Queensland
DEWHA	Department of the Environment, Water, Heritage and the Arts, Australia
DNA	Deoxyribonucleic acid
DPI&F	former Department of Primary Industries and Fisheries, Queensland
ELISA	Enzyme linked immuno sorbent assay
GPS	Global positioning system
IFGTB	Institute of Forest Genetics and Tree Breeding, India
NRMMC	Natural Resource Management Ministerial Council
NRMSC	Natural Resource Management Standing Committee
PVA	Population viability analysis
QPIF	Queensland Primary Industries and Fisheries
QPWS	Queensland Parks and Wildlife Service
QUT	Queensland University of Technology
RCV-A1	Rabbit calicivirus strain A1
RHD	Rabbit haemorrhagic disease
RHDV	Rabbit haemorrhagic disease virus
RT-PCR	Reverse transcriptase-polymerase chain reaction
SD	Standard deviation
SE	Standard error
TWRC	Tropical Weeds Research Centre
UK	United Kingdom
UQ	The University of Queensland
WONS	Weed(s) of National Significance

2. Herbicide and pesticide products

Name	Active ingredient(s)	Concentration	Manufacturer
1080 Concentrate	sodium fluoroacetate	180 g L^{-1}	Biosecurity Queensland
1080 pig bait solution	sodium fluoroacetate	36 g L^{-1}	Biosecurity Queensland
1080 dog bait solution	sodium fluoroacetate	6 g L^{-1}	Biosecurity Queensland
Ally®	metsulfuron methyl	600 g L^{-1}	DuPont (Australia) Ltd
Arsenal® Xpress	imazapyr + glyphosate	150 g L^{-1} + 150 g L^{-1}	Nufarm Australia Ltd
Curiosity® 1080 Cat Bait (6mg/125g)	sodium fluoroacetate	0.048 g kg^{-1}	Biosecurity Queensland
Grazon* DS	triclopyr + picloram	300 g L^{-1} + 100 g L^{-1}	Dow AgroSciences Australia Ltd
Hotshot*	aminopyralid + fluroxypyr	10 g L^{-1} + 140 g L^{-1}	Dow AgroSciences Australia Ltd
MOUSEOFF® ZP	zinc phosphide	2.5%	Animal Control Technologies
Roundup® Biactive	glyphosate	360 g L^{-1}	Nufarm Australia Ltd
Starane* Advanced	fluroxypyr	333 g L^{-1}	Dow AgroSciences Australia Ltd
Starane* 200	fluroxypyr	200 g L^{-1}	Dow AgroSciences Australia Ltd
Surefire® Zinc Phosphide Mouse Bait	zinc phosphide	2.5%	PCT International
Tordon* 75-D	2,4-D + picloram	300 g L^{-1} + 75 g L^{-1}	Dow AgroSciences Australia Ltd
Velpar® L	hexazinone	250 g L^{-1}	DuPont (Australia) Ltd
Weedmaster® Duo	glyphosate	360 g L^{-1}	Nufarm Australia Ltd
ZP Mouse	zinc phosphide	2%	Bell Laboratories

*Note: ® and * denote a registered trademark.*

3. Staff listings

Alan Fletcher Research Station

Brisbane

27 Magazine Street (PO Box 36)
Sherwood, Qld 4075
Tel: (07) 3375 0700
Fax: (07) 3379 6815
Email: donna.buckley@deedi.qld.gov.au

Name	Qualification	Designation
Gabrielle Vivian-Smith	PhD, BAgrSc, Grad.Dip.Hort., Dip.Bus.Mgt	Principal Scientist/Manager
Dane Panetta	PhD, BA	Principal Scientist and Professional Leader
Bill Palmer	PhD, MAgrSc, BRSc, QDAH	Principal Entomologist
K. Dhileepan	PhD, MSc, BSc	Principal Entomologist
Michael Day	BSc(Hons), ADAB, Dip.Bus.Mgt.	Senior Entomologist
Olusegun Osunkoya	PhD, MSc, BSc	Senior Scientist
Bob Parker	MAppSc, BAppSc, MRACI, CChem	Senior Scientist
Joseph Vitelli	BSc	Senior Weed Scientist
Tobias Bickel	PhD, MSc	Aquatic Weed Scientist
Karen Boundy	Bsc, ADRuralTech, QCAH	Scientist
Lesley Ruddle	BAppSc, CIC, ADAppChem	Scientist
Di Taylor	BSc(Hons)	Scientist
Ian Johnson	PhD, BSc(Hons), BAgrSc	Entomologist
Eve White	BSc(Hons)	CRC Postdoctoral Fellow
Annerose Chamberlain	BSc	Experimentalist
Amanda Dimmock	PhD, BAppSc(Hons)	Experimentalist
Erin Mawhinney	BSc	Experimentalist
Jayd McCarthy	BA, BAppSc	Experimentalist
Melinda McNaught	PhD, BSc(Hons)	Experimentalist
Christine Perrett	BSc	Experimentalist
Natasha Riding	BSc	Experimentalist
Wilmot Senaratne	MPhil, BSc(Hons)	Experimentalist
Matthew Shortus	BSc	Experimentalist
Nikki Sims-Chilton	BAppSc(Hons)/BIT	Experimentalist
Liz Snow	BSc(Hons)	Experimentalist
Mariano Trevino	BSc	Experimentalist
Alyson Weier	BSc	Experimentalist
Jens Froese	MA	Project Officer
Patrick Rogers	Dipl.Int.Tech., Cert.Rigger(Class 2), PestMgt. Techn. Lic., Boil.Op.(Basic), ACDC Comm.Op.Lic.	Senior Operations Supervisor
John Adler	Boil.Attend.(Class 3), Trade Cert.	Operations Officer
Mark Mitchell	ACDC Comm.Op.Lic., TruckLic.(HR)	Groundsperson
Daren Rodgers		Groundsperson
Donna Buckley		Administration Officer
Rose Broe	BSc	Image Archivist
Chandima Fernando	BSc	Experimentalist (Casual)
Stephen Caruana		Experimentalist (Casual)
Emily Strong		Assistant Scientist (Casual)
Asad Shabbir	MPhil, MSc	PhD student
Karina Pyle	BAppSc	Honours student
Manu Saunders	BSc	Honours student
Anita Kusumaningsih		Summer student
Richard Boyne		Summer student

Tropical Weeds Research Centre

Charters Towers

27–43 Natal Downs Road (PO Box 187)
Charters Towers, Qld 4820
Tel: (07) 4761 5700
Fax: (07) 4761 5757
Email: debra.haynes@deedi.qld.gov.au

Name	Qualification	Designation
Shane Campbell	PhD, BAppSc	Principal Scientist and Professional Leader
Jim Mitchell	PhD, MSc, BAppSc, Grad.Dip.T.	Senior Zoologist
Wayne Vogler	PhD, BAppSc	Senior Weed Scientist
Faiz Bebawi	PhD, MSc, BSc(Hons), Grad.Dip.Ed.	Weed Scientist
Simon Brooks	BSc(Hons)	Weed Scientist
Anita Randall		Weed Scientist
John McKenzie	BAgrSc	Rangeland Weeds Officer
Cathy Lockett	BSc(Hons)	Entomologist
Barbara Madigan	BSc	Experimentalist
Kelli Pukallus	BSc, Assoc.Dip.Sc.	Experimentalist
Dannielle Brazier	Dip.Cons.&LandMgt.	Experimentalist
William Green	BSc	Experimentalist
Patricia Voigt	BSc	Experimentalist
Beiha-Malen Yanez	BSc	Experimentalist
Debra Haynes		Centre Administration Officer
Chloe Kennedy		Administration Officer
Margaret Stevenson		Administration Officer
Rodney Stevenson		Operations Supervisor
Carl Anderson		Maintenance Officer
Chris Crowley		Scientific Assistant
Kirsty Gough		Scientific Assistant
Samuel Hughes		Scientific Assistant
Troy Johnson		Scientific Assistant
Christina Lockett		Scientific Assistant
Benjamin Madigan		Scientific Assistant
Ashley Owen		Scientific Assistant
Kyle Risdale		Scientific Assistant
Sharon Rossow		Scientific Assistant
Rebecca Stacey		Scientific Assistant
Clinton Hurst		Summer student
Daniel Warner		Summer student

South Johnstone (Centre for Wet Tropics Agriculture)

South Johnstone Road (PO Box 20)
South Johnstone, Qld 4859
Tel: (07) 4064 1130
Fax: (07) 4064 2249
Email: donna.vanhaaren@deedi.qld.gov.au

Name	Qualification	Designation
Melissa Setter	BAppSc, Adv.Cert.Hort.	Weed Scientist
Bill Dorney	BSc(Hons)	Experimentalist
Stephen Setter	BAppSc, ADBiolabTech	Experimentalist
Katie Patane	BEnvMan(Hons II)	Experimentalist

Robert Wicks Pest Animal Research Centre

Toowoomba

203 Tor Street (PO Box 102)
Toowoomba, Qld 4350
Tel: (07) 4688 1083
Fax: (07) 4688 1448
Email: jennifer.harvey@deedi.qld.gov.au

Name	Qualification	Designation
Tony Pople	PhD, BSc(Hons)	A/Principal Scientist and Professional Leader
Joe Scanlan	PhD, MAgrSc, BAgrSc(Hons)	Principal Scientist and Professional Leader
Lee Allen	PhD, MNatRes, BAppSc, JP(Comm. of Decl.)	Senior Zoologist
David Berman	PhD, BSc(Hons), Dip.Ed.	Senior Zoologist
Peter Cremasco	BAppSc	Zoologist
Julianne Farrell	BAppSc	Zoologist
Matt Gentle	PhD, BAppSc(Hons)	Zoologist
Annette Blair	BAppSc, ADAppSc	Experimentalist
Michael Brennan	BAppSc	Experimentalist
Damian Byrne	BAppSc	Experimentalist
James Speed	BAppSc	Experimentalist
Jennifer Harvey		Administration Officer

Inglewood

Millmerran Road (PO Box 178)
Inglewood, Qld 4387
Tel: (07) 4652 1599
Fax: (07) 4652 1295
Email: maria.granzotto@deedi.qld.gov.au

Name	Qualification	Designation
Peter Elsworth	BSc(Hons), Grad.Cert (Animal Welfare)	Experimentalist
David Aster	BSc	Experimentalist
Glen Rettke	Cert.Vet.Nursing	Equipment and Services Officer
Maria Granzotto		Administration Officer/Cleaner
Robert Thomson		Maintenance Officer
Brian Koina		Maintenance Officer

4. Publications

Journal articles

Bickel, T.O. and Closs, G.P. 2009. Impact of partial removal of the invasive macrophyte *Lagarosiphon major* (Hydrocharitaceae) on invertebrates and fish. *River Research and Applications* 25(6): 734–744.

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Books

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6. List of species

Scientific name	Common name
Acacia nilotica	prickly 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
Annona glabra	pond apple
Anredera cordifolia	Madeira vine
Apteromechus notatus	green pod-boring weevil
Araujia sericifera	white moth vine
Asparagus spp.	asparagus fern
Astrebla squarrosa	bull Mitchell grass
Azadirachta indica	neem tree
Azolla spp.	azolla
Basella alba	Ceylon spinach
Botryodiplodia theobromae	shoot tip die back
Bryophyllum delagoense	mother-of-millions
Bryophyllum spp.	mother-of-millions
Calotropis procera	calotrope (rubber bush)
Calycomyza eupatorivora	chromolaena leaf-mining fly
Camelus dromedarius	feral camel
Canis lupus familiaris	wild dog
Capra hircus	feral goat
Cardiospermum grandiflorum	balloon vine
Cardiospermum halicacabum	balloon vine
Carmenta ithacae	parthenium clear-wing moth
Carvalhotingis visenda	cat's claw creeper leaf-sucking tingid
Cascabella thevetia	Captain Cook tree (yellow oleander)
Cecidochares connexa	chromolaena gall fly
Cecropia peltata	Mexican bean tree
Cecropia palmata	trumpet tree
Cervus timorensis	rusa deer
Chromolaena odorata	chromolaena (Siam weed)
Cinnamomum camphora	camphor laurel
Clidemia hirta	clidemia (Koster's curse)
Clitoria ternatea	butterfly pea
Conotrachelus albocinereus	parthenium stem-galling weevil
Cylindrocopturus imbricatus	bellyache bush stem-boring weevil
Echeveria spp.	echeveria
Eichhornia crassipes	water hyacinth
Elephantopus mollis	tobacco weed
Epiblema strenuana	parthenium stem-galling moth
Falconia intermedia	lantana mirid
Felis catus	feral cat
Florestina tripteris	florestina
Formes sp.	formes heart rot
Fusarium sp.	fusarium root rot
Ganoderma lucidum	ganoderma root rot
Gmelina elliptica	badhara bush
Harungana madagascariensis	harungana
Heteropsylla spinulosa	mimosa psyllid
Hibbertia scandens	golden guinea flower snake vine
Hylaeogena jureceki	cats claw leaf-mining buprestid beetle
Hymenachne amplexicaulis	hymenachne
Hypocosmia pyrochroma	cat's claw creeper leaf-tying moth
Jatropha curcas	physic nut
Jatropha gossypiifolia	bellyache bush
Kalanchoe blossfeldiana	kalanchoe
Lantana camara	lantana
Lantana hirsuta	lantana
Lantana horrida	lantana
Lantana nivea	lantana
Lantana strigocamara	lantana
Lantana urticifolia	lantana
Lemna spp.	duckweed
Leucaena leucocephala ssp. *glabrata*	leucaena
Ligustrum lucidum	broad-leaf privet
Limnocharis flava	limnocharis
Macfadyena unguis-cati	cat's claw creeper
Macrophomina phaseolina	charcoal root rot
Melaleuca leucadendra	melaleuca
Melaleuca quinquenervia	melaleuca
Melaleuca viridiflora	melaleuca
Miconia calvescens	miconia
Miconia nervosa	miconia
Miconia racemosa	miconia
Mikania micrantha	mikania vine

Scientific name	Common name
Mimosa pigra	mimosa
Mimosa diplotricha	giant sensitive plant
Mus domesticus	house mouse
Myllocerus spp.	leaf weevil
Nassella tenuissima	Mexican feather grass
Neopaxia australasica	white purslane
Neptunia plena	water mimosa
Nigrospora oryzae	sporobolus leaf fungus
Oedium sp.	powdery mildew
Ophiomyia camarae	lantana herringbone leaf-mining fly
Opuntia tomentosa	velvety tree pear
Orobanche ramosa	branched broomrape
Oryctolagus cuniculus	rabbit
Osphilia tenuipes	mother-of-millions weevil
Pandorea jasminoides	bower of beauty vine
Pareuchaetes pseudoinsulata	chromolaena moth
Parsonsia straminea	monkey rope vine (silk pod vine)
Parthenium hysterophorus	parthenium
Phakopsora jatrophicola	bellyache bush rust fungus
Phenrica sp.	Madeira vine leaf beetle
Phyla canescens	lippia
Pistia stratiotes	water lettuce
Plectonycha correntina	Madeira vine leaf beetle
Prosopis pallida	mesquite
Prospodium tuberculatum	lantana rust
Pteroma sp.	bagworm
Puccinia lantanae	lantana rust
Puccinia melampodii	parthenium summer rust
Puccinia spegazzinii	mikania rust
Rattus sordidus	canefield rat
Ravenelia sp.	leaf rust
Salvinia spp.	salvinia
Salvinia molesta	salvinia
Scirtothrips aurantii	South African citrus thrips
Solanum mauritianum	wild tobacco
Spirodela spp.	duckweed
Sporobolus africanus	Parramatta grass
Sporobolus fertilis	giant Parramatta grass
Sporobolus jacquemontii	American rat's tail grass
Sporobolus natalensis	giant rat's tail grass
Sporobolus pyramidalis	giant rat's tail grass
Sus scrofa	feral pig
Tetramesa sp.	sporobolus stem wasp
Themeda quadrivalvis	grader grass
Thunbergia spp.	thunbergia
Uropyxis rickiana	cat's claw creeper rust fungus
Ustilago sporoboli-indici	sporobolus leaf smut
Verbena gaudichaudii	verbena
Vulpes vulpes	red fox
Ziziphus mauritiana	chinee apple
Zygogramma bicolorata	parthenium leaf-feeding beetle

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