Department of Employment, Economic Development and Innovation
Biosecurity Queensland

Technical highlights

Research projects 2010–11

Queensland Government

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Contents

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

Project dates

July 2006 – June 2015

Project leader

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Other staff in 2010–11

Laura Roden

Objectives

- Examine the effect of fire frequency and timing on grader grass biomass and overall pasture composition.
- Quantify the seed longevity of grader grass.

Rationale

Management of invasive grasses has received little attention compared to research undertaken on other exotic weeds. There is a general lack of understanding of appropriate control options, particularly ones that are economical to apply 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. The Queensland Government Department of Environment and Resource Management (DERM) has identified this as a critical conservation issue threatening biodiversity in national parks. Also, the pest management plans of several local governments identify the weed as a significant threat both economically and environmentally; the Mitchell River Watershed Management Group classifies it as a significant weed species.

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

Methods

Effect of fire frequency and timing

In a replicated plot trial we impose each treatment (fire during dry season, fire at start of wet season, fire at end of wet season) at yearly, two-yearly and four-yearly intervals. For comparison, we also apply the herbicide paraquat (concentration of 250 g L^{-1}) at 2 L ha^{-1} prior to seed set at yearly intervals. Changes in pasture species and biomass composition are measured using the Botanal methodology.

Progress in 2010–11

Seed longevity

Artificial seed-bank trials were completed in 2010. For the final results, see *Technical highlights 2009–10*.

Photo 1.1 Grader grass dominates a yearly burn plot at Undara National Park, 2011

Photo 1.2 Perennial grass dominates a herbicide plot at Undara National Park, 2011

Effect of fire frequency and timing

Grader grass biomass was generally maintained in yearly and two-yearly fire treatments applied at any time of year (Figures 1.1 and 1.2), except for the two-yearly late wet-season fire treatments in 2009 and 2011, where biomass was similar to that of the control and herbicide treatments (Figure 1.2). It is unclear at this stage why these reductions in grader grass biomass occurred, but they may be caused by the previous late wet-season fires (applied in 2008 and 2010) killing a large proportion of grader grass seed, resulting in lower populations in 2009 and 2011. Grader grass populations have then recovered in intervening years due to the disturbance caused by the 2008 and 2010 fires (Figure 1.2). In contrast, where disturbance was minimal (such as in the control and herbicide treatments), grader grass biomass continued to decline following the fourth year of treatment.

Where fire was excluded for four years following treatment, grader grass biomass declined to levels similar to those of the control and herbicide treatments in 2010 (Figure 1.3). Following application of the four-yearly fires in 2010, grader grass biomass in the late dry-season and early wet-season fire treatments in 2011 increased markedly; levels were similar to those in 2007 following the application of the first fire treatments in 2006 (Figure 1.3). Grader grass biomass in the late wet-season fire treatment remained similar to that in the control and herbicide treatments, as the four-yearly fire in this treatment was applied only after biomass measurements were conducted in the late wet season. The effect of late wet-season fires will be seen in following years.

These results continue to confirm that grader grass invasion and dominance is inherently related to the frequency of fire or other disturbances within pasture systems. They also suggest that minimising disturbance is a critical factor in reducing the presence and impact of this invasive grass.

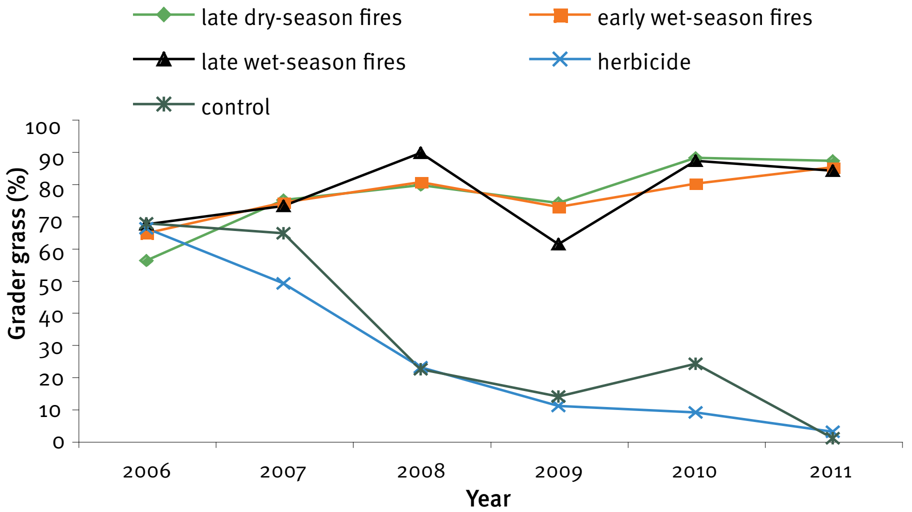

Figure 1.1 Grader grass response to yearly fires at Undara National Park

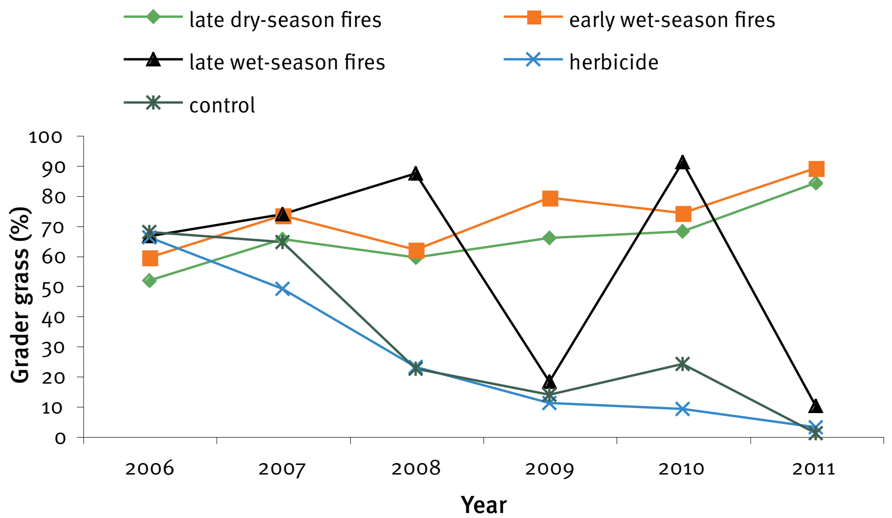

Figure 1.2 Grader grass response to two-yearly fires at Undara National Park

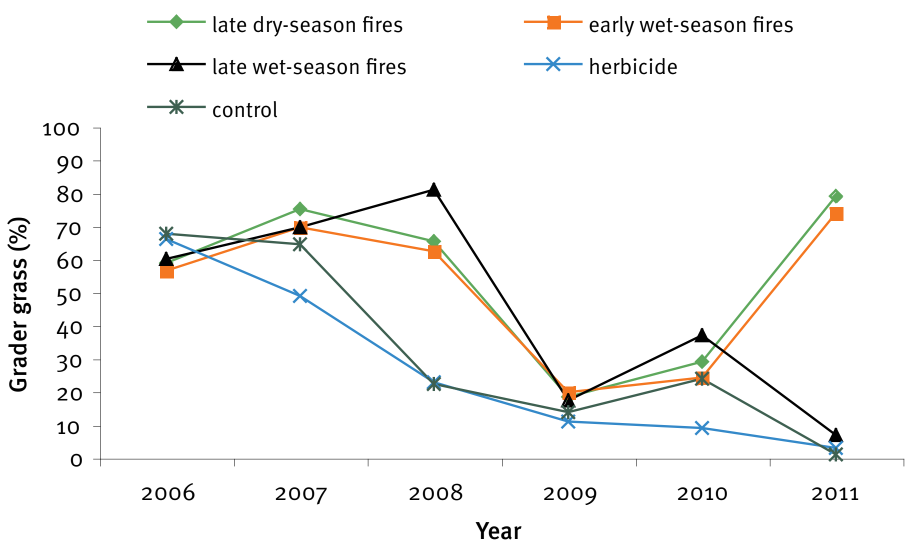

Figure 1.3 Grader grass response to four-yearly fires at Undara National Park

Funding in 2010–11

Queensland Government

Collaborators

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

More information

Key publications

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

Vogler, WD & Owen, NA 2008, 'Grader grass (*Themeda quadrivalvis*): changing savannah ecosystems', in RD van Klinken, VA Osten, FD Panetta & JC Scanlan (eds), *Proceedings of the 16th Australian Weeds Conference*, Queensland Weeds Society, Brisbane, p. 213.

Keir, AF & Vogler, WD 2006, 'A review of current knowledge of the weedy species *Themeda quadrivalvis* (grader grass)', *Tropical Grasslands* 40(4): 193–201.

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

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

Project dates

July 2000 – June 2011 (completed)

Project leader

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Other staff in 2010–11

Chris Crowley

Objectives

- Develop an integrated management strategy for bellyache bush.
- Evaluate the efficacy of combinations of fire, slashing and foliar herbicides on the 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 gaps in our knowledge about the seed ecology, competitive ability under different grazing pressures and population dynamics of bellyache bush. It also assesses the impact of integrated control techniques; this will help in developing strategies for best practice management.

Methods

This project includes two areas of research—integrated weed control and weed ecology of bellyache bush.

Integrated weed control

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

Weed ecology

Seed longevity (initiated in March 2001)

We bury two types of bellyache bush seeds (intact and ant-discarded) at six depths (0 cm on mulched ground; 0 cm on bare ground; depths of 5 cm, 10 cm, 20 cm and 40 cm) under two rainfall regimes (natural rainfall and rainfall-excluded).

Pasture management research (initiated in September 2002)

In a competition trial we determine the impact of five simulated grazing regimes:

1. no grazing (uncut pasture)
2. low grazing (cut at 40 cm height)
3. medium grazing (cut at 20 cm height)
4. high grazing (cut at 10 cm height)
5. no pasture (pasture removed).

These are applied to four plant densities:

1. control (no bellyache bush)
2. low density (2 plants m^{-2})
3. medium density (6 plants m^{-2})
4. high density (12 plants m^{-2}).

Findings

Integrated weed control

Field trials were completed in June 2006. For the final results, see *Technical highlights 2005–06*. A scientific paper on the results has now been published in *The Rangeland Journal*.

Weed ecology

Seed longevity

Under natural rainfall conditions, intact seeds exhumed were all expired after 36 months, compared with 72 months for ant-discarded seeds. At the rainfall-excluded site, all intact seeds expired 84 months after burial. However, ant-discarded seeds showed some signs of viability (average 1%) even 120 months after burial (Figure 2.1). There were significant interactions between burial conditions, seed types and burial depths (Figure 2.2). Generally seed viability declined with burial depths except for ant-discarded seeds, where it remained nearly constant over all burial depths under natural conditions. Intact seeds appear to be more sensitive to burial conditions and burial depth than ant-discarded seeds.

Pasture management research

There were significant interactions between treatment duration and simulated grazing regimes impacting on bellyache bush mortality (Figure 2.3). After 9 years, 55% of original bellyache bush plants died in areas void of pasture. In contrast, 73%, 77%, 77% and 79% mortality occurred in simulated regimes with no grazing, low grazing, medium grazing and high grazing, respectively.

Funding in 2010–11

Queensland Government

Collaborator

Ralph Woodard (Branmore Station)

More information

Key publications

Bebawi, FF, Vitelli, JS, Campbell, SD & Mayer, RJ 2011, 'Impact of control strategies on bellyache bush (*Jatropha gossypiifolia* L.) mortality, seedling recruitment, population dynamics, pasture yield and cost analysis', *The Rangeland Journal* 33(3): 277–86.

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

Bebawi, FF, Vitelli, JS, Campbell, SD, Vogler, WD, Lockett, CJ, Grace, BS, Lukitsch, B & Heard, TA 2007, 'The biology of Australian weeds 47. *Jatropha gossypiifolia* L.', *Plant Protection Quarterly* 22(2): 42–58.

Bebawi, FF, Cooper, AP, Brodie, GI, Madigan, BA, Vitelli, JS, Worsley, KJ & Davis, KM 2007, 'Effect of microwave radiation on seed mortality of rubber vine (*Cryptostegia grandiflora* R Br.), parthenium (*Parthenium hysterophorous* L.) and bellyache bush (*Jatropha gossypiifolia* L.)', *Plant Protection Quarterly* 22(4): 136–42.

Bebawi, FF, Mayer, RJ & Campbell, SD 2005, 'Flowering and capsule production of bellyache bush (*Jatropha gossypiifolia* L.)', *Plant Protection Quarterly* 20(4): 129–32.

Bebawi, FF, Mayer, RJ & Campbell, SD 2005, 'Phenology of bellyache bush (*Jatropha gossypiifolia* L.) in northern Queensland', *Plant Protection Quarterly* 20(2): 46–51.

Bebawi, FF & Campbell, SD 2004, 'Interactions between meat ants (*Iridomyrmex spadius*) and bellyache bush (*Jatropha gossypiifolia*)', *Australian Journal of Experimental Agriculture* 44(12): 1157–64.

Bebawi, FF & Campbell, SD 2002, 'Effects of fire on germination and viability of bellyache bush (*Jatropha gossypiifolia*) seeds', *Australian Journal of Experimental Agriculture* 42(8): 1063–9.

Bebawi, FF & Campbell, SD 2002, 'Impact of fire on bellyache bush (*Jatropha gossypiifolia*) plant mortality and seedling recruitment', *Tropical Grasslands* 36(3): 129–37.

Bebawi, FF & Campbell, SD 2002, 'The response of bellyache bush (*Jatropha gossypiifolia*) plants cut off at different heights and seasonal times', *Tropical Grasslands* 36(2): 65–8.

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

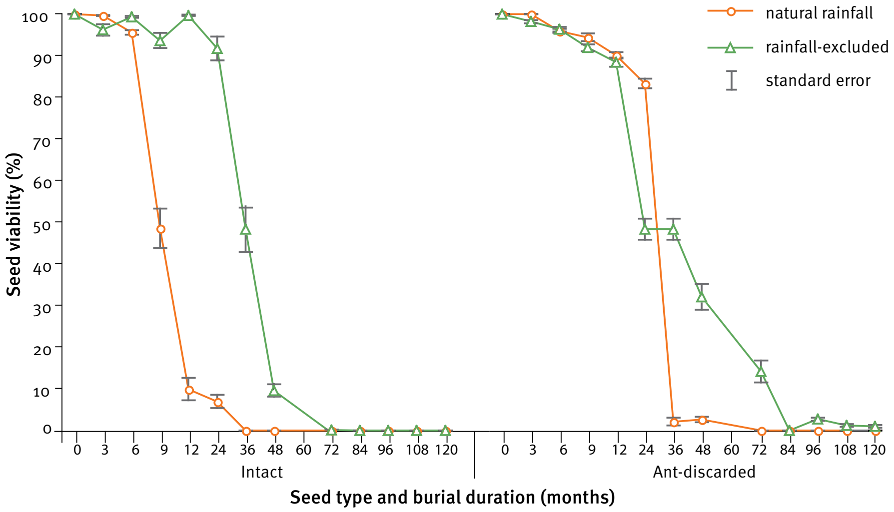

Figure 2.1 Viability of intact and ant-discarded seeds as affected by burial duration and rainfall regime, averaged over all burial depths

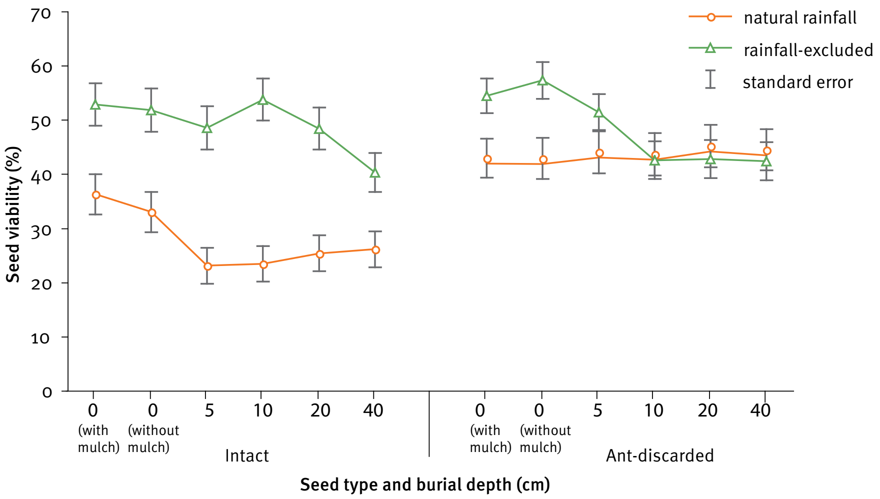

Figure 2.2 Viability of intact and ant-discarded seeds as affected by burial depth and rainfall regime, averaged over all years

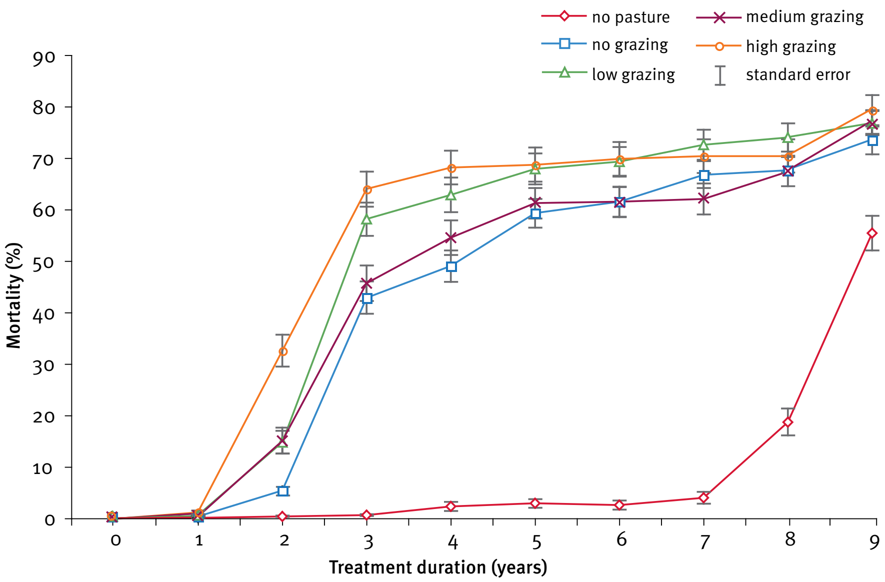

Figure 2.3 Mortality of bellyache bush plants as affected by simulated grazing regime and treatment duration, averaged over all plant densities

3. Ecology of Captain Cook tree (*Cascabela thevetia*) in northern Queensland

Project dates

July 2007 – June 2012

Project leader

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Other staff in 2010–11

Chris Crowley

Objective

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

Rationale

Captain Cook tree (*Cascabela thevetia*) is a Class 3 declared weed in Queensland. It is a garden escapee that has established some relatively large infestations in northern Queensland, particularly along banks 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. Dense infestations of this weed out-compete native pastures and reduce plant and animal biodiversity, as well as pasture productivity. It will continue to spread throughout its current range unless controlled. Understanding the ecology of Captain Cook tree is essential to developing effective management strategies and reducing its economic, environmental and social impacts.

Methods

This project entails six experiments, three of which are ongoing.

Experiment 2 (initiated in December 2007)

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

Experiment 3 (initiated in January 2008)

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

Experiment 6 (initiated in August 2009)

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

Progress in 2010–11

Experiments 1, 4 and 5 are completed. For key results, see *Technical highlights 2008–09* and *Technical highlights 2009–10*.

Experiment 2

This experiment is now completed, following the collection of three years of pod production data. Results show that pod production was significantly affected by flowering types, light conditions, plant density, months and years. Both flowering biotypes produced pods all year round although there was great variation between months (Figure 3.1). Yellow-flowering plants consistently produced more pods than peach-flowering ones across all treatments (Figure 3.2). For both flowering types, average pod production per plant was higher under full sunlight than under shaded conditions. Increased plant density also caused a decline in pod production for both flowering types (Figure 3.2)

Other key findings were reported in *Technical highlights 2008–09* and *Technical highlights 2009–10*.

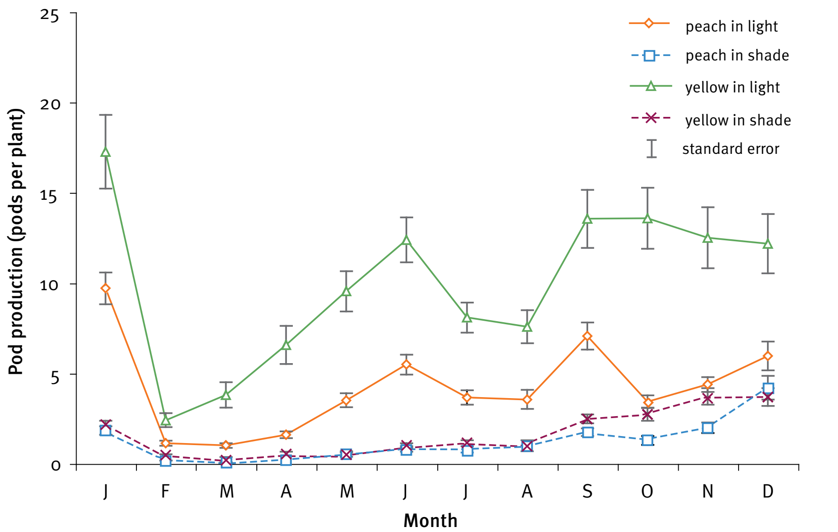

Figure 3.1 Pod production of the peach-flowering and yellow-flowering biotypes of Captain Cook tree as affected by months and light conditions

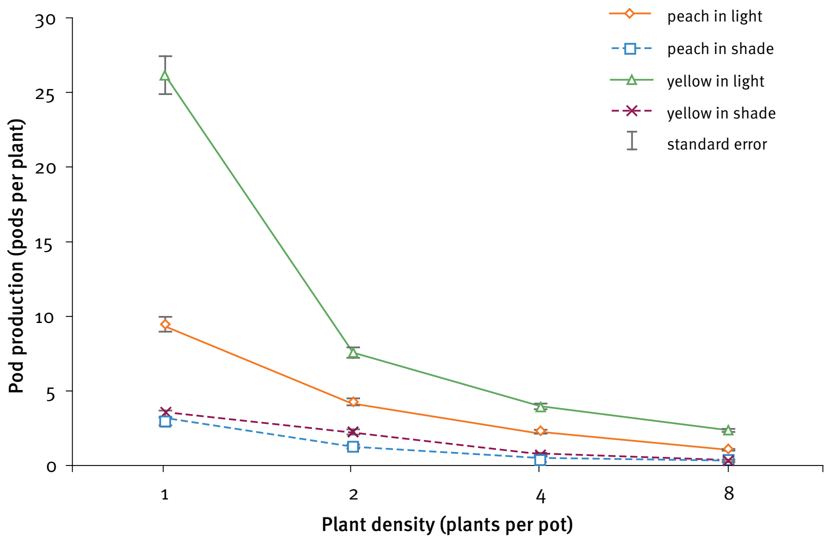

Figure 3.2 Pod production of the peach-flowering and yellow-flowering biotypes of Captain Cook tree as affected by plant densities and light conditions

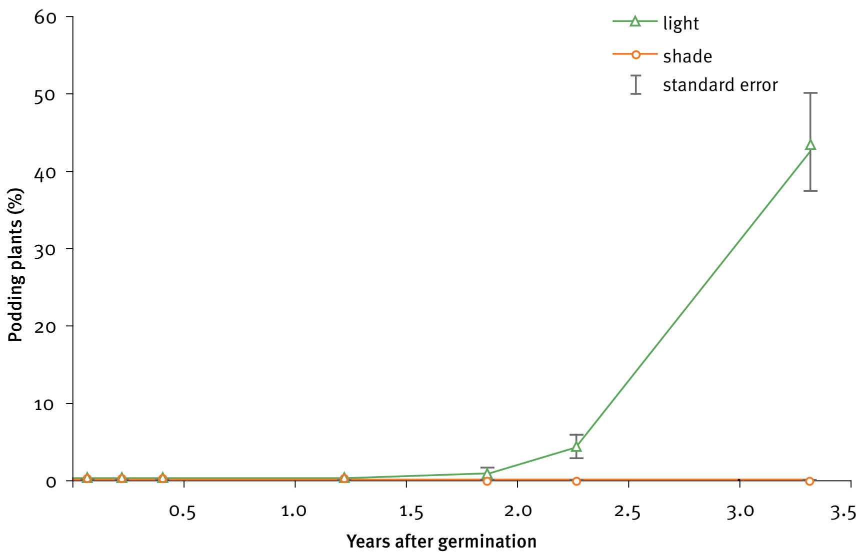

Figure 3.3 Percentage of peach-flowering plants producing pods under light and shaded conditions at Mingela

Experiment 3

Approximately 3.3 years after germination, 81% of peach-flowering plants exposed to full sunlight conditions were alive. In contrast, 45% of plants growing under full shade had died. Those remaining alive were on average 1.3 m and 0.4 m in height when grown under sunlight and shaded conditions, respectively. Furthermore, 44% of the original plants exposed to full sunlight have started producing pods, compared with no plants in shaded areas (Figure 3.3). The experiment is ongoing.

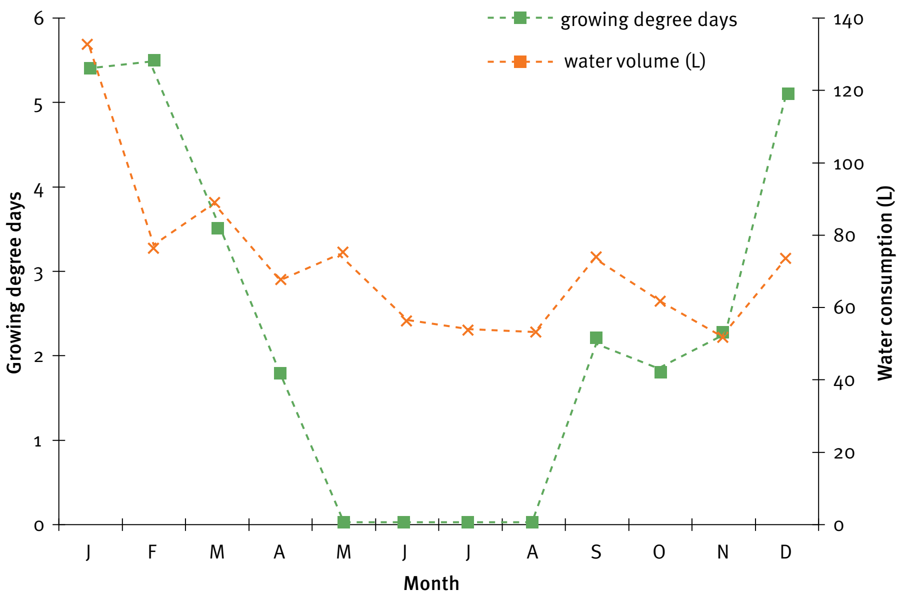

Figure 3.4 Water consumption of Captain Cook tree (across all size classes) associated with growing degree days

Experiment 6

Mature, adult and old Captain Cook trees consumed an average of 1023, 908 and 657 L of water per year, respectively. However, considerable variation in water consumption occurred on a monthly basis (Figure 3.4), and there was a strong correlation ($R^2 = 0.70$) between growing degree days and water consumption. Water consumption and the number of growing degree days were lowest during winter and highest during the summer months.

Funding in 2010–11

Queensland Government

Collaborators

- John Ramsey, Landholder (Meadow Vale Cattle Station, Mingela)
- Bob J. Mayer, Senior Biometrician [Department of Employment, Economic Development and Innovation (DEEDI), Oonoonba]
- Carole Wright, Biometrician (DEEDI, Oonoonba)

More information

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

4. Weed seed dynamics

Project dates

August 2007 – June 2020

Project leader

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Other staff in 2010–11

Chris Crowley

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 abovementioned 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 priority species in central and northern Queensland.

Methods

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

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

Progress in 2010–11

Preliminary results suggest that chinee apple, Captain Cook tree, calotrope, neem and yellow bells have short-lived seed banks, with no viable seed recorded after 24 months burial. To confirm this finding, we buried a fresh batch of seeds of chinee apple and the peach-flowering variety of Captain Cook tree in October 2010 to expose them to another set of environmental conditions. Fresh viable seed of calotrope are currently sourced for a repeat burial.

Mesquite has also demonstrated a rapid loss of viable seed from the seed bank following burial (< 1% viability after 24 months burial). In contrast, prickly acacia, leucaena, lantana and parthenium are showing a greater level of persistence.

Gamba grass from the Cape York region was added to the trial in June 2010.

Funding in 2010–11

- Land Protection Fund ($47 000)
- Queensland Government

Collaborators

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

More information

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

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

Project dates

June 2010 – June 2014

Project leader

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Other staff in 2010–11

Chris O'Donnell, Laura Roden, Kelli Pukallus and Wayne Vogler

Objective

Develop improved control options for calotrope.

Rationale

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

A national literature review by Grace (2006) and a workshop sponsored by Meat and Livestock Australia (MLA) in 2007 identified key gaps in our understanding of the invasiveness and impacts of calotrope and our ability to manage it. These included distribution and rate of spread, reproductive biology, grazing effects and methods of control.

This project is part of a larger collaborative MLA-funded research project aimed at addressing these knowledge gaps. Biosecurity Queensland is focusing on improving control options, while other aspects are being investigated primarily by Charles Darwin University and the Northern Territory Government Department of Natural Resources, Environment, The Arts and Sport (NRETAS).

Methods

Establishment of an advisory committee

An advisory committee, initially set up after the 2007 MLA workshop, has been re-established to oversee the project and ensure it achieves its objectives. An initial stakeholder workshop was held to present the proposed research program and ensure that it is appropriate to address critical information gaps on calotrope.

Foliar herbicide control

To compare new and unregistered foliar herbicides with currently available options, we conduct a split-plot experiment comprising 22 herbicide treatments (main plot) and two plant sizes (sub-plot) on a property in Queensland's gulf country. Chemicals tested include metsulfuron-methyl, 2,4-D, triclopyr, triclopyr + picloram, fluroxypr, aminopyralid + fluroxypr, 2,4-D + picloram, triclopyr + picloram + aminopyralid, 2,4-D + picloram, metsulfuron-methyl + 2,4-D, and four new unregistered formulations (one from DuPont Australia and three from Dow AgroSciences). The most effective herbicides will be further trialled to refine rates and test for seasonal effects.

Practical options for control of isolated plants

We also aim to identify herbicide products and techniques that can be easily and practically used as part of day-to-day activities to control isolated calotrope plants without using excessive equipment. Firstly, we conduct an experiment at the same location as the foliar herbicide trial using two herbicides (Vigilant® gel and Roundup Powermax®) as either a cut stump or frill application. Secondly, we test the efficacy of tebuthiuron at a site near Charters Towers, with pellets applied either around the plant's drip zone or at the base of the stem, to test the efficacy of a residual herbicide and determine if the placement location of the pellets is important.

Mechanical control

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

Herbivory study

To help quantify whether biological control agents could deleteriously affect the growth and development of calotrope, we undertake a simulated herbivory study in the glasshouse at TWRC. Potted calotrope plants (*C. procera* and *C. gigantea*) are grown until they are 14 weeks old and are then subjected to one of seven damage levels (nil, leaf, stem, root, leaf + stem, leaf + root, stem + root) either once, twice or three times at eight-weekly intervals. We monitor their growth, development and reproductive status at each interval before destructively harvesting all plants eight weeks after the third treatment.

Progress in 2010–11

Establishment of an advisory committee

The advisory committee—comprising representatives from state and territory governments, pastoral companies, natural resource management bodies, community groups and Charles Darwin University—had its inaugural meeting at Katherine in 2010. A stakeholder workshop was held afterwards to discuss the proposed research program.

Foliar herbicide control

We applied herbicides in April 2010, with several products showing good brownout soon after. Monitoring will continue for 12–24 months, given calotrope's ability to remain dormant and reshoot many months after treatment.

Practical options for control of isolated plants

The cut stump or frill application and the tebuthiuron experiment commenced in June 2010 and February 2011 respectively.

Photo 5.1 Experimentalist Laura Roden (left) and scientific assistant Kirsty Gough inspect flowers on *C. gigantea* and *C. procera* during the simulated herbivory trial

Herbivory study

We have initiated the herbivory study in March 2011, with both the single and double treatments now imposed.

Other activities

A monitoring site was established on Helen Springs Station to assess the efficacy of basal bark and tebuthiuron control (undertaken by a commercial contractor). Data analysis is in progress.

Collaborators at Charles Darwin University have recently commenced studies into the ecology of calotrope and identified a suitable PhD candidate to join their team.

Reference

Grace, BS 2006, 'The biology of Australian weeds 45. *Calotropis procera* (Aiton) W.T. Aiton', *Plant Protection Quarterly* 21(4): 152–60.

Funding in 2010–11

- MLA ($90 000)
- Queensland Government

Collaborators

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

More information

Key publication

Vitelli, J, Madigan, B, Wilkinson, P & van Haaren, P 2008, 'Calotrope (*Calotropis procera*) control', *The Rangeland Journal* 30(3): 339–48.

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

6. Herbicide application research

Project dates

June 2008 – ongoing

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Other staff in 2010–11

Dannielle Brazier

Objectives

- Evaluate the effectiveness of chemical control techniques, including basal bark spraying, foliar spraying, cut stump, stem injection and splatter gun spraying, on Captain Cook tree.
- Evaluate the effectiveness of stem injection on prickly acacia, chinee apple and calotrope.
- Evaluate the effectiveness of splatter gun spraying on bellyache bush.

Rationale

Captain Cook tree (*Cascabela thevetia*) is a Class 3 weed. It is a garden escapee that has established some relatively large infestations in northern Queensland, particularly along the banks of the Douglas River and major creeks of the lower and upper Burdekin catchment near Mingela and Ravenswood. Developing effective control techniques is essential to stopping the continued spread of this weed. Presently, there is no registered chemical available for its control.

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

There is also a need for a highly mobile control technique (such as splatter gun spraying) to control bellyache bush in inaccessible locations where it is not possible to use vehicle-mounted foliar spray equipment.

Methods

Captain Cook tree trials

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

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

Stem injection trials

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

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

Bellyache bush splatter gun trial

We conduct a splatter gun screening trial on bellyache bush. Each treatment is replicated three times and individual plots comprise 20 plants. For this trial we use an NJ Phillips Powermaster Forestry™ applicator with a portable LPG power supply. Chemicals are applied at 4 mL for each 50 cm of plant height. Herbicides used in this trial have generally been found effective when using foliar application methods.

Progress in 2010–11

Captain Cook tree trials

From the rate screening trials, we have identified chemicals and application rates that will provide high mortality of Captain Cook tree using basal bark spraying, foliar spraying, cut stump and stem injection techniques (Table 6.1). Fluroxypyr has proven most effective for basal bark spraying, foliar spraying and cut stump applications, while glyphosate caused the highest mortality using stem injection. Stem injection, cut stump and basal bark spraying can be applied at any time of the year with no variation in final results. However, plants that are treated when they are not actively growing tend to send out stem suckers in the first season. While they eventually succumb to the treatment in the next season, they take longer to die. Further work is required to finetune the methodology and rates used in the splatter gun trial.

Stem injection trials

Calotrope

Herbicides, application rates and efficacy in the rate screening trial conducted near Georgetown (along the Gilbert River) are summarised in Table 6.2. Compared with the initial screening trial (reported in *Technical highlights 2009–10*), mortality in all treatments was low. The fact that plants at the Georgetown site had almost twice the cross-sectional area as plants at Greenvale may have contributed to these results.

Table 6.1 Mortality of Captain Cook tree using various treatments and active ingredients in the rate screening trials

Treatment[a]	Active ingredient	Rate and carrier	Mortality (%)[b]
Basal bark	fluroxypyr (333 g L^{-1})	1:112 diesel	85*
Basal bark[c]	fluroxypyr (333 g L^{-1})	1:112 diesel	98†
Basal bark	control	1 diesel	0‡
Basal bark[c]	control	1 diesel	0‡
Cut stump	fluroxypyr (333 g L^{-1})	1:112 water + wetter	100†
Cut stump	fluroxypyr (333 g L^{-1})	1:55 water + wetter	100†
Cut stump	fluroxypyr (333 g L^{-1})	1:55 diesel	100†
Cut stump	control	diesel	21*
Cut stump	control	water + wetter	12*
Foliar	fluroxypyr (333 g L^{-1})	1:334 water + wetter	77†
Foliar	fluroxypyr (333 g L^{-1})	1:167 water + wetter	92†
Foliar	aminopyralid (10 g L^{-1}) fluroxypyr (140 g L^{-1})	1:140 water + wetter	72†
Foliar	triclopyr (300 g L^{-1}) + picloram (100 g L^{-1}) + aminopyralid (8 g L^{-1})	1:300 water + wetter	11*
Foliar	control	water + wetter	5*
Stem injection	glyphosate (360 g L^{-1})	1:0 water	97†
Stem injection	glyphosate (360 g L^{-1})	1:0	97†
Stem injection	triclopyr (200 g L^{-1}) + picloram (100 g L^{-1})	1:4 water + wetter	90†
Stem injection	triclopyr (200 g L^{-1}) + picloram (100 g L^{-1})	1:4 water	96†
Stem injection	control	water + wetter	0*
Stem injection	control	water	0*
Splatter gun	fluroxypyr (333 g L^{-1})	1:9 water + wetter	91†
Splatter gun	aminopyralid (10 g L^{-1}) fluroxypyr (140 g L^{-1})	1:3 water + wetter	93†
Splatter gun	glyphosate (360 g L^{-1})	1:9 water + wetter	61*
Splatter gun	control	water + wetter	0‡

a Stem injection treatments refer to the second rate screening trial; splatter gun treatments refer to the initial screening trial.

b Mortality values followed by the same symbol are not significantly different, $p < 0.05$.

c Double application height (1 m above ground) was used.

Table 6.2 Mortality of calotrope in the stem injection rate screening trial

Active ingredient	Rate and carrier	Mortality (%)[a]
triclopyr (200 g L^{-1}) + picloram (100 g L^{-1})	1:4 water + wetter	20*
2,4-D (300 g L^{-1})+ picloram (75 g L^{-1})	1:3 water + wetter	9*
2,4-D (625 g L^{-1})	1:7 water + wetter	10*
glyphosate (360 g L^{-1})	1:0 water + wetter	24*
glyphosate (360 g L^{-1})	1:1 water + wetter	13*
imazapyr (150 g L^{-1}) + glyphosate (150 g L^{-1})	1:4 water + wetter	72†
control	water + wetter	0‡

a Mortality values followed by the same symbol are not significantly different, $p < 0.05$.

Prickly acacia

Herbicides, application rates and efficacy 18 months after treatment in the rate screening trial are summarised in Table 6.3. Compared with the initial screening trial (reported in *Technical highlights 2009–10*), mortality in all treatments was low. The presence of seed pods on test plants or particular choices in the way treatments were applied may have influenced overall efficacy. We have now established a second rate screening trial, using the same rates but different cut spacing (label-recommended and 7 cm) and adding a wetter to all treatments. Plants in this trial also do not have developing pods.

Chinee apple

Herbicides, application rates and efficacy two years after treatment in the initial screening trial are summarised in Table 6.4. Mortality in all treatments was low, with a maximum of only 16% recorded.

Bellyache bush splatter gun trial

Herbicides, application rates and efficacy two years after treatment in the initial screening trial are summarised in Table 6.5. Metsulfuron-methyl has proven highly effective and we will now undertake additional work to refine application rates.

Table 6.3 Mortality of prickly acacia in the stem injection rate screening trial

Active ingredient	Rate and carrier	Mortality (%) 18 months after treatment[a]
triclopyr (200 g L^{-1}) + picloram (100 g L^{-1})	1:4 water	22†
2,4-D (300 g L^{-1})+ picloram (75 g L^{-1})	1:1.5 water	9†
glyphosate (360 g L^{-1})	1:0.5 water	0*
control	water	0*

a Mortality values followed by the same symbol are not significantly different, $p < 0.05$.

Table 6.4 Mortality of chinee apple in the stem injection screening trial

Active ingredient	Rate and carrier	Mortality (%) 24 months after treatment[a]
triclopyr (200 g L^{-1}) + picloram (100 g L^{-1})	1:4 water + wetter	16†
2,4-D (300 g L^{-1}) + picloram (75 g L^{-1})	1:1.5 water + wetter	14†
2,4-D (625 g L^{-1})	1:6 water + wetter	0*
imazapyr (150 g L^{-1}) + glyphosate (150 g L^{-1})	1:4 water + wetter	1*
glyphosate (360 g L^{-1})	1:2 water + wetter	0*
hexazinone (250 g L^{-1})	1:2 water + wetter	0*
control	water + wetter	0*

a Mortality values followed by the same symbol are not significantly different, $p < 0.05$.

Table 6.5 Mortality of bellyache bush in the splatter gun screening trial

Active ingredient	Rate and carrier	Mortality (%)[a]
fluroxypyr (333 g L^{-1})	1:17 water + wetter	48*
glyphosate (360 g L^{-1})	1:9 water + wetter	54*
metsulfuron-methyl (600 g kg^{-1})	2 g L^{-1} water + wetter	99†
control	water + wetter	0‡

a Mortality values followed by the same symbol are not significantly different, $p < 0.05$.

Funding in 2010–11

- Land Protection Fund ($76 000)
- Queensland Government

More information

Key publications

Brazier, D, McKenzie, J, Owen, A, Campbell, SD, Vitelli, JS, Reid, A & Mayer, R 2010, 'Evaluating herbicides for the control of the invasive weed florestina (*Florestina tripteris* DC.)', in SM Zydenbos (ed.), *Proceedings of the 17th Australasian Weeds Conference*, New Zealand Plant Protection Society, Christchurch, New Zealand, pp. 421–3.

McKenzie, J, Brazier, D, Owen, A, Vitelli, JS & Mayer, R 2010, 'Stem injection: a control technique often overlooked for exotic woody weeds', in SM Zydenbos (ed.), *Proceedings of the 17th Australasian Weeds Conference*, New Zealand Plant Protection Society, Christchurch, New Zealand, pp. 459–61.

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

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

Project dates

December 2007 – December 2010 (completed)

Project leader

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Other staff in 2010–11

Barbara Madigan

Objective

Evaluate the effectiveness of the EZ-Ject™ herbicide lance in controlling woody weeds in Queensland using both glyphosate-filled and imazapyr-filled shells.

Rationale

Using 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 imazapyr) 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.

To trial this control method, three woody weeds were chosen, each from a different family and each infesting a different area of Queensland. Captain Cook tree (*Cascabela thevetia*), family Apocynaceae, is a Class 3 weed that is highly toxic and invades native vegetation. Velvety tree pear (*Opuntia tomentosa*), family Cactaceae, is a Class 2 weed 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 weed. 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 the 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

Captain Cook tree 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 imazapyr) 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.

Findings

This study established that the EZ-Ject herbicide system is an effective tool for controlling individual woody plants, although the degree of control varied among species, with efficacy influenced by herbicide and number of cartridges injected.

Cartridges filled with imazapyr were significantly more effective than those filled with glyphosate at controlling the three woody weed species. Injecting plants with three imazapyr cartridges resulted in mortalities of 93–100%, compared to mortalities of 17–100% for glyphosate cartridges. Pond apple was the most susceptible species, requiring one imazapyr cartridge to kill 97% or two glyphosate cartridges to kill 92% of treated plants. Plant mortality increased as the number of cartridges injected increased. However, mortality did not differ significantly for treatments receiving three and four imazapyr cartridges, as the lower cartridge density already met the manufacturer's recommendation of injecting one cartridge per 10 cm basal circumference when treating large plants (> 6.35 cm diameter at breast height).

Photo 7.1 Bullets of water-soluble herbicide injected into the base of woody weeds

The cost of using three cartridges per tree to treat a weed infestation of 1500 plants ha^{-1} is \$1070 ha^{-1}, with labour costs accounting for 16% of this. The high chemical costs would preclude this technique from broad-scale use, but it could be valuable for treating woody weeds in sensitive areas, including those with high conservation values.

Agribusiness will be canvassed to identify businesses interested in importing and distributing the herbicide lance and capsules. Once an importer has been identified, a consent-to-import permit will be sought from the Australian Pesticides and Veterinary Medicines Authority (APVMA) so that land managers can purchase the equipment.

Funding in 2010–11

Queensland Government

More information

Key publication

Vitelli, JS & Madigan, BA 2011, 'Evaluating the efficacy of the EZ-Ject herbicide system in Queensland, Australia', *The Rangeland Journal* 33(3): 299–305.

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

Project dates

July 2007 – June 2012

Project leader

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Other staff in 2010–11

Mariano Treviño

Objectives

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

Rationale

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

Methods

Staff from the CSIRO Mexican Field Station and CABI Europe – United Kingdom (CABI Europe–UK), through other collaborative links, collect fresh spore material of *Phakopsora jatrophicola* ex *J. gossypiifolia* from different geographic regions and send them to facilities at Egham, United Kingdom.

In order to quantify the degree of susceptibility of individual *J. gossypiifolia* varieties towards particular *P. jatrophicola* strains, we inoculate rust strains from Brazil, Trinidad and the Pacific coast of Mexico on the three varieties Queensland Bronze, Queensland Green and Queensland Purple. The rust strain most virulent towards all Queensland varieties of *J. gossypiifolia* is then selected for full host-specificity tests conducted under quarantine by our collaborators at CABI Europe–UK.

Progress in 2010–11

All three Queensland bellyache bush varieties were susceptible to all three rust strains, but the strain from Trinidad showed consistently high virulence on all three Queensland bellyache bush varieties (Figure 8.1). The strains from Brazil and Trinidad were also less virulent than the previously assessed rust strain from El Zapote, Mexico, towards the non-target plant *J. curcas*. Because of its comparatively high virulence towards all Queensland varieties of *J. gossypiifolia* and its low virulence towards *J. curcas*, the strain from Trinidad was selected for host-specificity testing.

Full host-specificity testing of the rust strain from Trinidad has commenced. In March 2011, we exported a shipment of 13 test plant species (10 plants each) to CABI Europe–UK. The evaluation status and test results of the 13 non-target species are summarised in Table 8.1. The rust caused restricted sporulation on *J. multifida* as well as on one individual plant of *J. integerrima* with hirsute leaves. Other individuals of *J. integerrima* exhibiting non-hirsute, waxy leaves proved to be less susceptible. *J. podagrica* showed chlorotic and necrotic leaf spots, but no sporulation, following inoculation. No macroscopic symptoms or sporulation were evident on other test plant species.

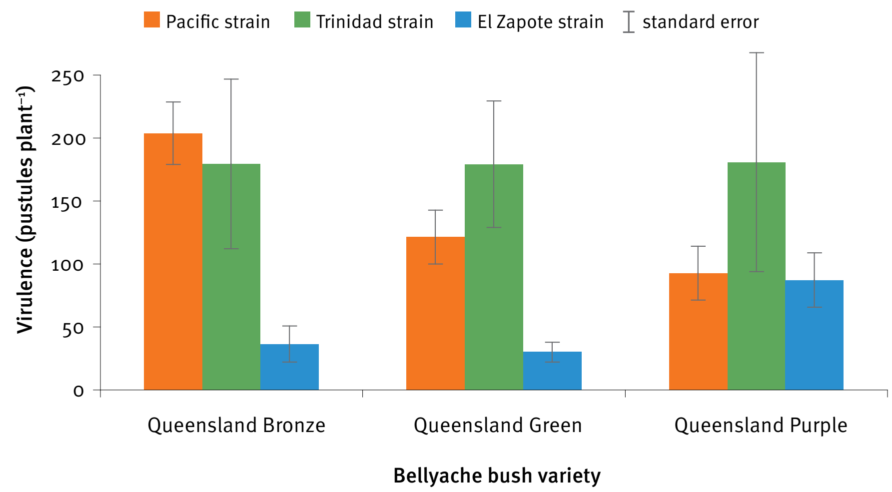

Figure 8.1 Virulence of three strains of *P. jatrophicola* towards the three Queensland bellyache bush varieties

Table 8.1 Response of 13 non-target test plant species to inoculation with the *P. jatrophicola* strain from Trinidad

Family	Test plant species	No-choice host-specificity test results
Euphorbiaceae	*Jatropha integerrima*	Restricted sporulation in a plant with hirsute leaves and not on plants with normal leaves
	Jatropha multifida	Restricted sporulation
	Jatropha podagrica	Chlorotic and necrotic leaf spots; no sporulation
	Aleurites moluccana	Necrotic leaf spots; no sporulation
	Manihot esculenta	Some chlorotic leaf spots (not associated with the rust); no sporulation
	Euphorbia pulcherrima	Occasionally protuberances (not associated with the rust); no sporulation
	Alchornea ilicifolia	No macroscopic symptoms
	Macaranga tanarius	No macroscopic symptoms
Phyllanthaceae	*Cleistanthus dallachyanus*	Under evaluation
	Breynia oblongifolia	Small pinhole-like necrotic leaf spotting; no sporulation
	Antidesma parvifolium	Under evaluation
Picrodendraceae	*Petalostigma pubescens*	Under evaluation
Putranjivaceae	*Drypetes deplanchei*	Under evaluation

Funding in 2010–11

- Land Protection Fund ($47 000)
- MLA ($30 000)
- Queensland Government (Blueprint for the Bush)

Collaborators

- Marion Seier (CABI Europe–UK, United Kingdom)
- Tim Heard (CSIRO Ecosystem Sciences, Brisbane)
- Ricardo Segura (CSIRO Ecosystem Sciences, Mexican Field Station)
- Tanya Scharaschkin (Queensland University of Technology, Science and Engineering Faculty)

More information

Key publications

Heard, TA, Chan, RR, Senaratne, KADW, Palmer, WA, Lockett, CJ & Lukitsch, B 2009, '*Agonosoma trilineatum* (Heteroptera: Scutelleridae) a biological control agent of the weed bellyache bush, *Jatropha gossypiifolia* (Euphorbiaceae)', *Biological Control* 48(2): 196–203.

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Bebawi, FF, Vitelli, JS, Campbell, SD, Vogler, WD, Lockett, CJ, Grace, BS, Lukitsch, B & Heard, TA 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 Biosecurity Queensland website at www.biosecurity.qld.gov.au

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

Project dates

May 2007 – June 2014

Project leader

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Other staff in 2010–11

Mariano Treviño and Kelli Pukallus

Asad Shabbir and Ruey Toh (The University of Queensland PhD students)

Objectives

- Monitor the field persistence and abundance of parthenium biological control agents.
- 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 for this weed. Among the various biological control agents introduced against parthenium in Queensland, the summer rust (*Puccinia xanthii* var. *parthenii-hysterophorae*, previously reported as *P. melampodii*) is an agent suited to areas with hot and dry weather conditions. It was introduced from Mexico in 1999 and released at more than 50 infested sites in Queensland. The clear-wing moth (*Carmenta ithacae*), also native to Mexico, was released from 1998 to 2002. The stem-galling weevil (*Conotrachelus albocinereus*) from Argentina was released in Queensland from 1995 to 2000. Although all three agents have established in the field, their incidence and abundance in parthenium infestations in central and northern Queensland is not fully known.

The role of competition from beneficial plants in managing parthenium is widely known. So far, however, no information is available on the potential role of various native and introduced pasture plants in enhancing the effectiveness of parthenium biological control agents in Australia. Identification of beneficial plants exhibiting high competitive indices, in particular under changing climate—specifically elevated carbon dioxide (CO_2)—would help to manage parthenium more effectively.

Methods

Biological control agent monitoring

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

Biological control and competitive plants under elevated CO_2

We conduct an experiment in controlled-environment rooms to quantify the combined effect of a stem-galling biological control agent (*Epiblema strenuana*) and plant suppression by buffel grass (*Cenchrus ciliaris*) on parthenium's vegetative and reproductive growth under ambient CO_2 levels of 380 parts per million by volume (ppmv) and under elevated CO_2 levels (550 ppmv).

Parthenium canopy architecture

Parthenium canopy architecture is studied under three temperature (day/night 22/15 °C, 27/20 °C, and 32/25 °C in thermal time 12/12 hours) and two CO_2 (ambient and elevated) regimes in controlled-environment rooms. Identical light (photoperiod 12 hours, ~ 250 µmol s^{-1}) and relative humidity (65%) are maintained in all rooms. We track plant development from the ninth day after transplantation using three-dimensional digitising every third day with a sonic digitiser. The last measurement is made after about 550 growing degree days. From empirical data, we develop a virtual three-dimensional canopy architecture model of a parthenium plant using the modelling software L-systems.

Progress in 2010–11

In central Queensland, we surveyed 17 sites in March 2011. Surveys at three sites in northern Queensland were conducted in April 2011.

Parthenium summer rust

The summer rust was evident at all sites with parthenium infestations. The proportion of infected plants was high at all three sites in northern Queensland (Cardigan Station, Felspar and Plain Creek), but the proportion of leaves with rust infection remained low at all these sites (Figure 9.1). In central Queensland, parthenium was evident in only 7 of the 17 sampling sites, but the summer rust was observed at all sites with parthenium infestations. The proportion of plants and leaves infected varied widely between sites (Figure 9.1).

Parthenium clear-wing moth

We have previously confirmed field establishment of the clear-wing moth at 5 of the 13 release sites and 2 nearby non-release sites in central Queensland. In 2011 the clear-wing moth was recovered from a non-release site near Carfax, confirming its continued persistence in the field. High summer rainfall resulting in flooding could have affected the root-boring larvae at many sites.

Parthenium stem-galling weevil

The stem-galling weevil was not recovered in any of the survey sites. Limited establishment of this agent could be due to the dominance of the stem-galling moth (*E. strenuana*) in all parthenium-infested areas. The stem-galling moth and the stem-galling weevil share a similar feeding niche.

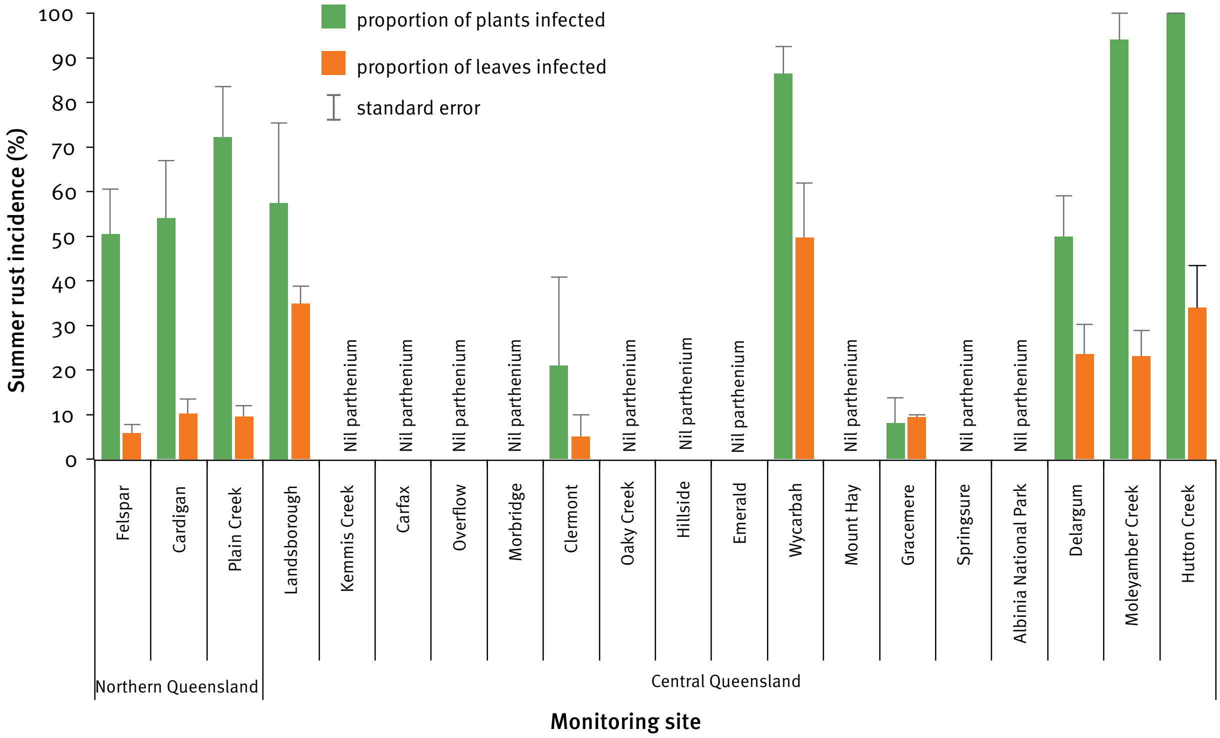

Figure 9.1 Incidence of *P. xanthii* var. *parthenii-hysterophorae* in Queensland

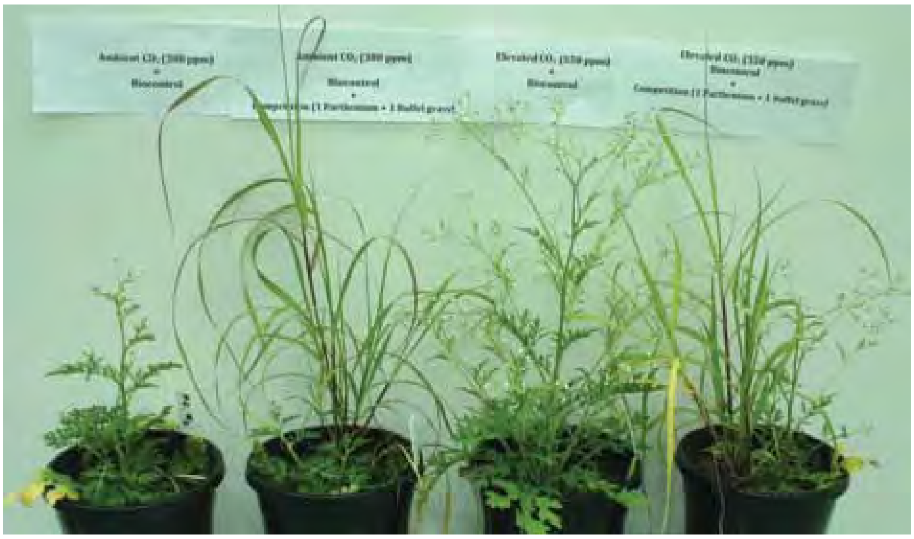

Photo 9.1 Impact of plant competition and biological control on parthenium growing under ambient (380 ppmv) and elevated (550 ppmv) CO_2 levels

Biological control and competitive plants under elevated CO_2

The experiment was carried out from May to July 2011. With biological control (*E. strenuana*), parthenium grew much more vigorously and produced significantly more biomass and more flowers under elevated CO_2 than under ambient CO_2. In contrast, buffel grass became less competitive and produced fewer tillers and less biomass under elevated CO_2 than under ambient CO_2 (Photo 9.1). This suggests that under climate change, biological control with *E. strenuana* and competition from buffel grass may not be effective.

Parthenium canopy architecture

A virtual three-dimensional canopy architecture model of a parthenium plant was developed. Both temperature and CO_2 regimes significantly affected parthenium canopy size and structure. We currently use the virtual plant model to study the implications of changes in the parthenium canopy due to climate change on parthenium summer rust infection levels.

Funding in 2010–11

- Queensland Government
- AusAID ($8000)

Collaborators

Prof. Steve Adkins (School of Land, Crop and Food Sciences, The University of Queensland)

More information

Key publications

Dhileepan, K & Strathie, L 2009, '*Parthenium hysterophorus* L. (Asteraceae)', in R Muniappan, GVP Reddy & A Raman (eds), *Biological control of tropical weeds using arthropods*, Cambridge University Press, Cambridge, pp. 272–316.

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

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

Project dates

January 2007 – June 2014

Project leader

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Other staff in 2010–11

Catherine Lockett, Di Taylor and Mariano Treviño

A. Balu, M. Senthilkumar, S. Murugesan and P. Senthilkumar (Institute of Forest Genetics and Tree Breeding, Coimbatore, India)

Syed Irfan Ahmed, Sangeetha Singh, Mahadeo Gorain and Anamika Sharma (Arid Forest Research Institute, Jodhpur, India)

Objectives

- Survey and assess the host range of insects and pathogens associated with prickly acacia in the native range (India).
- Conduct host-specificity tests on prioritised biological control agents for prickly acacia.

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 north-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 as well as 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

Native range surveys

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.

Exclusion studies

The impact of native insect herbivores on seedling survival and growth under field conditions is evaluated in exclusion trials conducted over a two-year period 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 maintain 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). They sample the potted plants at quarterly intervals and record the incidence and abundance of various insects, along with details of several plant parameters (e.g. defoliation levels, plant height, number of leaves, number of branches, basal stem diameter, above-ground and below-ground biomass). This information is used for prioritising agents for more detailed studies, including host-specificity tests.

Host-specificity tests

Specialist insect herbivores and plant pathogens exhibiting host-specificity in field surveys are tested in no-choice and choice trials in the glasshouse and field cages to confirm host-specificity. After importing prioritised agents into the quarantine at the Ecosciences Precinct, we conduct host-specificity testing of two agents, the leaf-webbing caterpillar (*Phycita* sp.) and the babul scale (*Anomalococcus indicus*), involving over 80 species of test plants. No-choice host-specificity testing of the gall-inducing rust (*Ravenelia acaciae-arabicae*) is conducted on 17 species of closely related Australian acacia species in the quarantine at CABI Europe–UK. The plants necessary for the testing are sent from Australia either as potted plants or seeds.

Progress in 2010–11

Native range surveys

Surveys continued at the predetermined sites in Tamil Nadu and Karnataka in southern India and in Gujarat and Rajasthan in north-western India.

In southern India, the gall-inducing rust (*R. acaciae-arabicae*) was observed at 10 of the 72 survey sites, all in Tamil Nadu. Rust uredinia and telia are found predominantly on the upper surface of leaflets, while spermagonia occur on fruits, inflorescences and shoot tips, with aecia causing hypertrophy on fruits, inflorescences and shoot tips, resulting in galls. Field surveys suggest that *R. acaciae-arabicae* is specific to *A. nilotica* ssp. *indica*, as the rust was not observed on other *A. nilotica* subspecies or other *Acacia* species (e.g. *A. ferruginea, A. latronum, A. auriculiformis, A. catechu, A. leucophloea* and *A. farnesiana*) co-occurring with *A. nilotica* ssp. *indica* in India.

In north-western India, a second leaf rust (*R. evansii*) was recorded at three sites in Gujarat.

Exclusion studies

Results from exclusion trials in Gujarat and Rajastahan were reported in *Technical highlights 2009–10*. Trials in Tamil Nadu have now also concluded. At both sites native insect herbivores reduced plant height, basal stem diameter, number of branches, number of leaflets, leaf biomass, stem biomass and root biomass (Figures 10.1 and 10.2). Reductions in plant vigour at both sites were primarily due to the babul scale (*A. indicus*) infesting shoots.

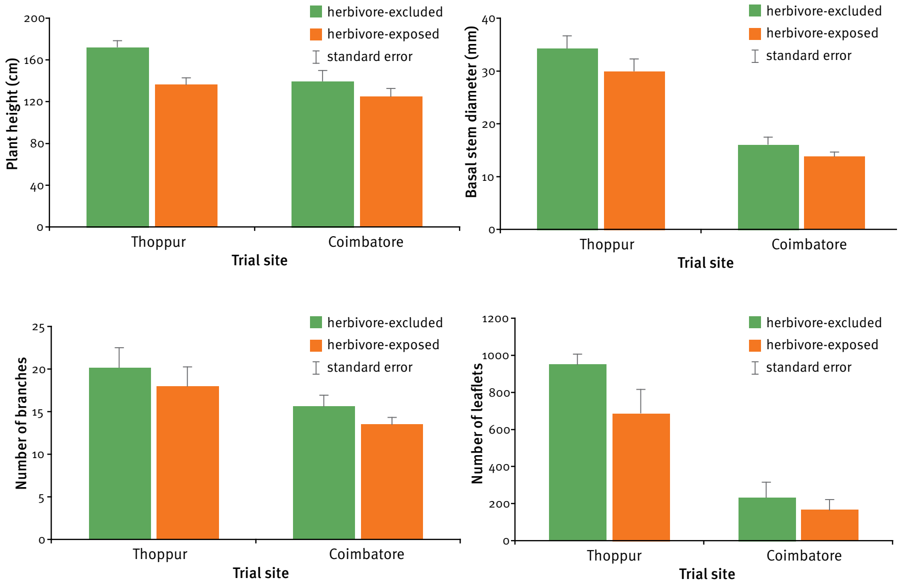

Figure 10.1 Impact of insect herbivores on plant height, basal stem diameter, number of branches and number of leaflets of prickly acacia seedlings in Tamil Nadu, India

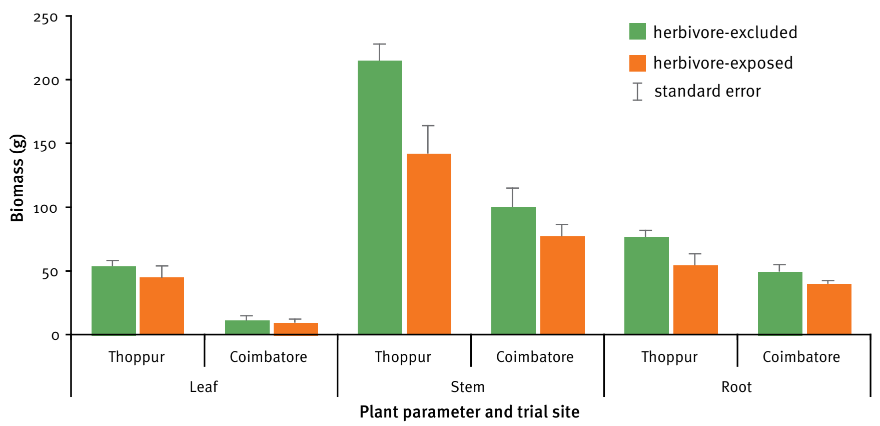

Figure 10.2 Impact of insect herbivores on biomass of prickly acacia seedlings in Tamil Nadu, India

Host-specificity tests

India

In no-choice tests, the semi lopper (*Isturgia disputaria*) larvae fed and completed development on two non-target acacias (*A. planifrons* and *A. leucophloea*), but the proportion of larvae completing development and emerging as adults was significantly less on *A. planifrons* (30%) and *A. leucophloea* (10%) than on *A. nilotica* (100%). No larval development occurred on other test plants (*A. mellifera, A. ferruginea, A. auriculiformis, A. catechu, A. farnesiana, A. deanei, A. tortilis* and *Delonix regia*).

The leaf-webbing caterpillar (*Phycita* sp.) fed and completed development under no-choice conditions on two non-target acacias (*A. planifrons* and *A. leucophloea*), but the proportion of larvae completing development and emerging as adults remained much higher (100%) on the target weed (*A. nilotica*) than on *A. planifrons* (30%) and *A. leucophloea* (40%). No larval feeding or development was evident on other test plants (*A. mellifera, A. ferruginea, A. auriculiformis, A. catechu, A. farnesiana, A. deanei, A. tortilis, Anacardium occidentale* and *Mangifera indica*).

Babul scale (*A. indicus*) crawlers (first instar nymphs) settled and survived on one non-target plant species (*A. tortilis*) in no-choice tests. The rate of survival and development of nymphs on the non-target plant in comparison to prickly acacia is being studied. No crawler establishment or nymphal development occurred on other test plants (*A. planifrons, A. leucophloea, A. mellifera, A. ferruginea, A. auriculiformis, A. catechu, A. farnesiana, A. deanei* and *Piper nigrum*).

The leaf-feeding weevil (*Dereodus denticollis*) fed on *A. auriculiformis* leaves under no-choice conditions. Although adult weevils nibbled on the leaves of other test plants (*A. farnesiana* and *A. tortilis*) initially, no adults survived beyond three days. No adult feeding was evident on other test plants (*A. mellifera, A. ferruginea, A. catechu* and *A. deanei*).

Australia

Approvals to export three prioritised agents (*Phycita sp., A. indicus* and *D. denticollis*) from India to Australia were obtained from the National Biodiversity Authority India and from the Ministry of Environment and Forestry, Government of India. Subsequently, permits to import these agents into Australia were obtained from the relevant Australian regulatory authorities. We imported the three agents into a quarantine facility at the Alan Fletcher Research Station in January 2011 and later transferred them to the new quarantine facility at the Ecosciences Precinct. Since then, we have established cultures of two agents (*Phycita* sp. and *A. indicus*) and are currently conducting no-choice host-specificity tests involving Australian *Acacia* species.

United Kingdom

The gall-inducing rust (*R. acaciae-arabicae*) was imported into quarantine facilities of CABI Europe–UK on leaves of *A. nilotica* ssp. *indica* in October 2010. At CABI, the rust (IMI 398973 ex Tamil Nadu, India) was established and maintained as a uredinial infection (Photo 10.1) on Australian *A. nilotica* plants under quarantine greenhouse conditions. The rust completed its urediniospore infection cycle—from spore penetration to sporulation and uredinia formation—on average in 21 days. The rust also regularly produced teliospores within existing uredinia, but spermogonia or aecia were not observed on inoculated *A. nilotica* plants.

An initial host-specificity assessment of the rust (IMI 398973) on 17 *Acacia* species under quarantine greenhouse conditions showed that the pathogen evoked a range of macroscopic symptoms on the non-target species. These varied in consistency and intensity. With the exception of *Acacia sutherlandii, R. acaciae-arabicae* was not able to sporulate on any of the evaluated test plant species, internal mycelium (if present) was always limited, and the initiation of uredinia was not observed. *A. sutherlandii*, native to Queensland, is not a reported host of *R. acaciae-arabicae* or of *R. evansii* (the name under which the rust was previously known), but under greenhouse conditions the rust was able to produce uredinia bearing viable urediniospores on this non-target species (Photo 10.2). Sporulation was, however, less prolific than that observed on *A. nilotica* and was always accompanied by strong plant defence responses. Furthermore, although urediniospores of *R. acaciae-arabicae* produced on *A. sutherlandii* were viable, re-inoculation of the spores onto *A. nilotica* and *A. sutherlandii* resulted in successful sporulation only on the natural host *A. nilotica*. Possible reasons for this could be either a loss of virulence in urediniospores cycling through *A. sutherlandii* or a lower concentration of spore inoculum applied due to the initially limited production of *R. acaciae-arabicea* on *A. sutherlandii*.

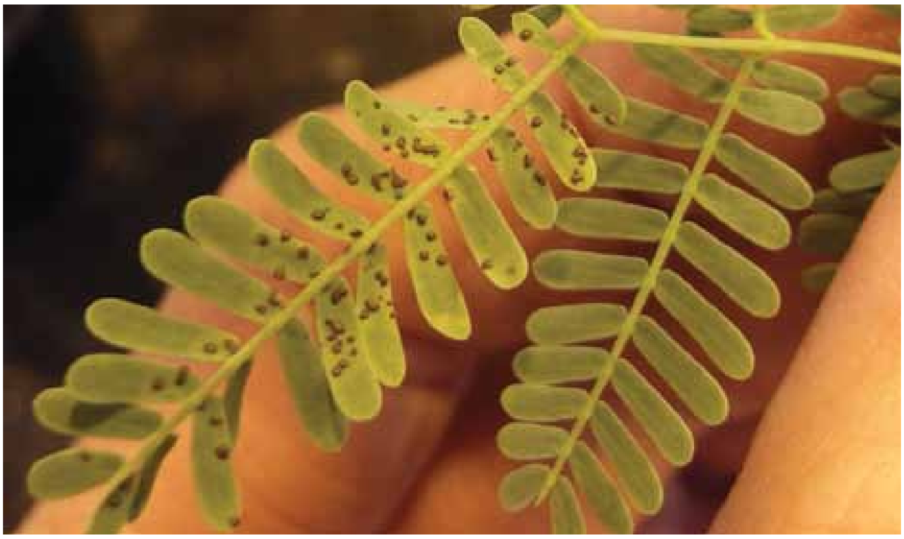

Photo 10.1 Uredinia of *R. acaciae-arabicae* on *A. nilotica* ssp. *indica* leaves

Photo 10.2 Uredinia of *R. acaciae-arabicae* on *A. sutherlandii* leaves

Funding in 2010–11

- MLA ($85 000)
- Rural Industries Research and Development Corporation ($41 000)
- Land Protection Fund ($38 000)
- Queensland Government

Collaborators

- Roger Shivas, Principal Plant Pathologist (DEEDI)
- Marion Seier (CABI Europe–UK, United Kingdom)
- 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 R Muniappan, GVP Reddy & A Raman (eds), *Biological control of tropical weeds using arthropods*, Cambridge University Press, Cambridge, pp. 17–37.

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

Dhileepan, K, Senaratne, KADW & 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): 303–07.

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

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

Project dates

October 2009 – June 2012

Project leader

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Other staff in 2010–11

Peter Jones

Objectives

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

Rationale

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

Methods

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

Photo 11.1 A male *D. tomentosus* fertilising a mature female (hidden underneath waxy secretion)

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

Progress in 2010–11

In August 2010, collaborator Dr Carla Chavez Moreno hand-carried a population of *D. tomentosus* collected on the required host *C. rosea* to Australia, where it was placed in quarantine. However, the insect could not use Australian populations of Hudson pear nor other *Cylindropuntia* spp. presently found in Australia. The culture was maintained on Mexican cladode material for many months but all attempts to rear it on Australian material failed.

We are now attempting to culture other populations of *D. tomentosus*: a population infesting *C. kleiniae* was obtained from South Australia and host testing commenced; a population currently giving effective biological control of *C. fulgida* in South Africa will also be imported.

We have also arranged for genetic studies to be undertaken on *C. rosea* from Mexico and Spain, *C. fulgida* from South Africa and most of the Australian *Cylindopuntia* spp. in order to have an improved understanding of the taxonomy of this genus.

Given the problems encountered with *D. tomentosus* from Mexico, the question remains whether Hudson pear in Australia is really *C. rosea* or perhaps a hybrid. Linking our Hudson pear with similar genotypes in Mexico would also enable appropriate native range collections of *D. tomentosus*.

Funding in 2010–11

New South Wales Government Department of Primary Industries ($31 000)

Collaborators

- Royce Holtkamp (New South Wales Government Department of Primary Industries)
- Catherine Mathenge (University of Western Sydney)
- Carla Chavez Moreno (University of Michoacan, Mexico)
- Mayra Pérez and Sandi Cuen (Aridamerica AC, Mexico)
- Helmuth Zimmermann (Helmuth Zimmermann & Associates, South Africa)

More information

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

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

Project dates

January 2000 – July 2012

Project leader

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Other staff in 2010–11

Wilmot Senaratne and Liz Snow

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 the Alan Fletcher Research Station, 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

Potential biocontrol agents are imported for host-specificity testing in quarantine. If approval for release is 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 appropriate ministerial council. If the ministerial council unanimously supports the application, a biological control authority will seek the views of all stakeholders and determine the benefits and costs of the proposed biological control. If, on balance, the benefits outweigh costs, the ministerial council may by unanimous opinion approve the declaration of target and agent organisms under the Act.

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

Progress in 2010–11

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. The insects were relocated to the new quarantine facility at the Ecosciences Precinct in February 2011.

Additional host testing of both insect species was undertaken following the discovery that naturalised populations previously considered to be *Kalanchoe crenata* were now considered to be *Kalanchoe spathulata*. The results of this testing suggested that this plant was a good host for both insect species.

An application for agent release through the *Biological Control Act 1987* was submitted to the Australian Weeds Committee for discussion. With the support of this committee, an application was made to and approved by the Primary Industries Ministerial Council. The next step is to prepare nationwide notification and invite affected stakeholders to respond.

The PhD student's field studies of *S. aurantii* indicated that additional biocontrol agents would be desirable to control mother-of-millions effectively.

Funding in 2010–11

Land Protection Fund ($73 000)

Collaborators

- Dr Bruce Wilson, General Manager, Invasive Plants and Animals (Biosecurity Queensland)
- Michelle Rafter, PhD student (The University of Queensland)

More information

Key publications

McLaren, DA, Palmer, WA & Morfe, TA 2006, 'Costs associated with declaring organisms through the *Biological Control Act* when conflicts of interest threaten weed biological control projects', in C Preston, JH Watts & ND Crossman (eds), *Proceedings of the 15th Australian Weeds Conference*, Weed Management Society of South Australia, Adelaide, pp. 549–52.

Witt, ABR 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, ABR, McConnachie, AJ & 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): 380–87.

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

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

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

Project dates

September 2002 – June 2014

Project leader

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Other staff in 2010–11

Di Taylor and Mariano Treviño

Objective

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

Rationale

Cat's claw creeper (*Macfadyena unguis-cati*), an invasive liana native of Central and South America, is a major weed in coastal Queensland and New South Wales, where it poses a significant threat to biodiversity in riparian and rainforest communities. The plant is a structural parasite and produces stolons and subterranean root tubers. Biological control appears the most suitable management option for this weed. Management objectives focus 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

Host-specificity tests

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

Field-release and monitoring

We mass-rear and field-release two biological control agents, the leaf-sucking tingid (*Carvalhotingis visenda*) and leaf-tying moth (*Hypocosmia 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* and *H. pyrochroma*. 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 and *H. pyrochroma* larvae.

Progress in 2010–11

Host-specificity tests

We completed host-specificity tests of the leaf-mining buprestid beetle (*H. jureceki*) in quarantine at the Ecosciences Precinct in May 2011. These tests support previous studies from South Africa indicating that the beetle is highly host-specific and does not pose risk to any non-target plants in Australia. Minor exploratory adult feeding occurred on eight non-target species and oviposition on one non-target species, but larval development occurred only on *M. unguis-cati*. Observations indicate that this is a highly damaging insect with two destructive life stages: larvae mine within the leaves and adults chew holes into leaves. Under laboratory conditions, high populations can completely defoliate cat's claw creeper plants. A short generation time, long-living adults and predator-evading characteristics suggest that rapid population growth is likely in the field. We have applied to the relevant regulatory authorities to release this agent in Australia.

Field-release and monitoring

No further field-releases of the leaf-sucking tingid (*C. visenda*) were made after June 2010. Field-release of the leaf-tying moth (*H. pyrochroma*) was continued until October 2010. Over three years, 1272 adult moths, 77 750 mature larvae and 837 pupae have been released across 36 sites in Queensland and New South Wales. Field establishment status of the moth was not monitored due to relocation to the Ecosciences Precinct.

Funding in 2010–11

- Land Protection Fund ($148 000)
- Queensland Government (Blueprint for the Bush)

Collaborators

- Stefan Neser and Anthony King [Agricultural Research Council—Plant Protection Research Institute (ARC-PPRI), South Africa]
- Dr Tanya Scharaschkin (Queensland University of Technology, Science and Engineering Faculty)
- Local government and community groups across south-eastern and central Queensland

More information

Key publications

Dhileepan, K, Treviño, M, Bayliss, D, Saunders, M, Shortus, M, McCarthy, J, Snow, EL et al. 2010, 'Introduction and establishment of *Carvalhotingis visenda* (Hemiptera: Tingidae) as a biological control agent for cat's claw creeper *Macfadyena unguis-cati* (Bignoniaceae) in Australia', *Biological Control* 55(1): 58–62.

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Conrad, KA & 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): 303–11.

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Raghu, S, Dhileepan, K & Scanlan, JC 2007, 'Predicting risk and benefit a priori in biological control of invasive plant species: a systems modelling approach', *Ecological Modelling* 208(2–4): 247–62.

Raghu, S, Dhileepan, K & Treviño, M 2006, 'Response of an invasive liana to simulated herbivory: implications for its biological control', *Acta Oecologica* 29(3): 335–45.

Raghu, S, Wilson, JR & Dhileepan, K 2006, 'Refining the process of agent selection through understanding plant demography and plant response to herbivory', *Australian Journal of Entomology* 45(4): 308–16.

Raghu, S & Dhileepan, K 2005, 'The value of simulating herbivory in selecting effective weed biological control agents', *Biological Control* 34(3): 265–73.

Dhileepan, K, Treviño, M, Donnelly, GP & Raghu, S 2005, 'Risk to non-target plants from *Charidotis auroguttata* (Chrysomelidae: Coleoptera), a potential biocontrol agent for cat's claw creeper *Macfadyena unguis-cati* (Bignoniaceae) in Australia', *Biological Control* 32(3): 450–60.

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

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

Project dates

June 2007 – June 2013

Project leader

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Other staff in 2010–11

Wilmot Senaratne, Liz Snow and Peter Jones

Objective

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

Rationale

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

Methods

Surveys for suitable biological control agents of Madeira vine are conducted in Argentina and Brazil by Dr Stefan Neser from the ARC-PPRI, South Africa. We import those insects considered suitable, mainly as a result of host testing undertaken in South Africa, into quarantine facilities in Australia for final host-specificity testing and biology studies. We also develop climate-matching models for prospective agents. We then seek approval from the relevant regulatory authorities to release any suitable agents. Approved agents are then mass-reared for distribution to climatically favourable areas. Following release, we monitor establishment progress and evaluate any effects of the agents.

Progress in 2010–11

Host-specificity testing of the Madeira vine leaf beetle (*Plectonycha correntina*) concluded in late 2009 and showed that the beetle could use only Madeira vine as a host. The release of *P. correntina* for the biological control of Madeira vine was therefore recommended in a report submitted to Australian regulatory authorities in December 2009. The case for this insect was the first to be processed through Biosecurity Australia's new protocols for biological control agents.

In early 2011, both regulatory authorities approved the submissions, and the insect was released from quarantine in April 2011.

Mass-rearing of the insect commenced immediately within non-quarantine glasshouses at the Ecosciences Precinct. The insect was reared most satisfactorily in these facilities and produced sufficient numbers to begin field releases.

By June 2011, we had released over 2000 beetles, primarily in the western suburbs of Brisbane. Due to the approaching winter, this was not an optimal time for insect survival. However, these releases will help us gain a better understanding of the insect's overwintering capabilities.

We have also provided adult beetles to the New South Wales Government Department of Primary Industries. This is to establish a mass-rearing program at the Grafton research station to provide insects for release in New South Wales.

Dr Neser made a further exploratory trip to South America in the hope of finding populations of the leaf beetle *Phenrica* sp. or other potential biocontrol agents, but no insect species was forthcoming. It would be highly desirable to begin research on a second agent to supplement *P. correntina* eventually.

Photo 14.1 Experimentalist Liz Snow releases *P. correntina* on a Brookfield property with very heavy Madeira vine infestation

Funding in 2010–11

- Land Protection Fund ($193 000)
- Queensland Government

Collaborators

- Dr Stefan Neser and Liamé van der Westhuizen (ARC-PPRI, South Africa)
- New South Wales Government Department of Primary Industries

More information

Key publications

Cagnotti, C, McKay, F & 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): 300–09.

Vivian-Smith, G, Lawson, BE, Turnbull, I & Downey, PO 2007, 'The biology of Australian weeds 46. *Anredera cordifolia* (Ten.) Steenis', *Plant Protection Quarterly* 22(1): 2–10.

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

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

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

Project dates

Ongoing

Project leaders

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Other staff in 2010–11

Natasha Riding and Kelli Pukallus

Objective

Import, evaluate host-specificity of, 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 that this weed costs the grazing industry over $100 million each year in lost production and control expenses. Lantana can become the dominant understorey species in natural ecosystems, blocking succession and decreasing biodiversity. Lantana is a Class 3 declared weed in Queensland and has been the target of biocontrol programs since 1914. Introducing new and more effective biocontrol agents further enhances control of lantana and reduces dependency on chemicals and other control methods.

Methods

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

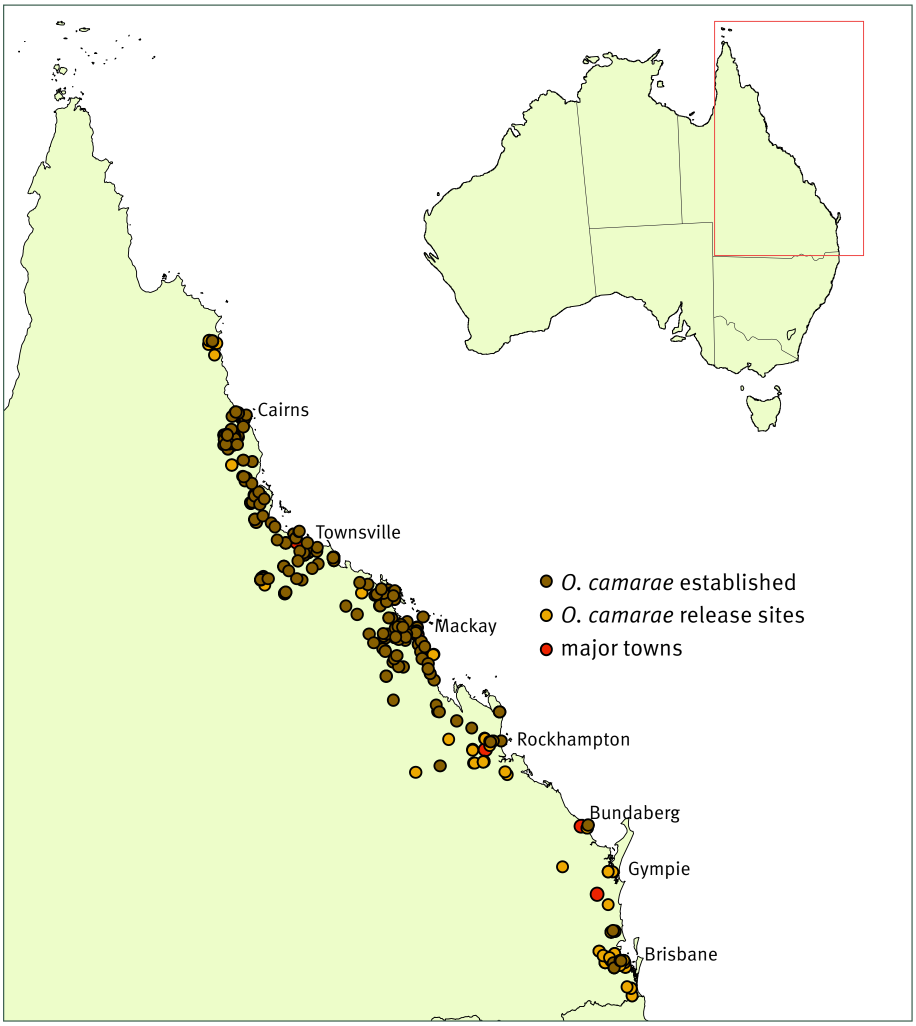

Figure 15.1 Current distribution of *O. camarae* in Queensland

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

Progress in 2010–11

The lantana herringbone leaf-mining fly (*Ophiomyia camarae*) continues to be mass-reared at TWRC for field-release. However, field-releases in south-eastern Queensland have stopped, since the fly appears to be more suited to tropical regions. Leaf mines have been found at more than 200 sites from Cooktown to Shoalwater Bay, with insects moving up to 50 km away from some release sites. There has been substantial defoliation of lantana bushes around Cooktown and Ayr. In south-eastern Queensland, the fly has been found in low numbers at only a few sites. Here, apart from having to cope with the cooler conditions, the fly has to compete with other biocontrol agents, particularly *Calycomyza lantanae* and *Uroplata girardi*.

To comply with Australian regulatory authorities, we contracted ARC-PPRI to conduct host-specificity testing of the lantana budmite (*Aceria lantanae*). The studies found the budmite was sufficiently specific to release. We have now gained approval from Biosecurity Australia to release the budmite. Approval from the Australian Government Department of Sustainability, Environment, Water, Population and Communities is pending.

Photo 15.1 Galls on lantana caused by *A. lantanae*

We have imported *A. lantanae* into the quarantine at the Ecosciences Precinct and are currently testing it against the main lantana phenotypes in Australia. It readily causes gall formation on the red-flowering and pink-edged red-flowering types, and causes some gall formation on the orange-flowering type. However, gall formation has not been observed on the common pink-flowering type. Field-releases are expected to commence in the summer of 2011–12.

We contracted CABI Europe–UK to study the biology, biotype preference and host-specificity of the pathogen *Puccinia lantanae*. Investigations found some infection on the native *Verbena officinalis* var. *africana* (previously reported as *V. gaudichaudii*) and *V. officinalis* var. *gaudichaudii* as well as the weed *Phyla canescens*. A report has been received and a decision about conducting further testing is pending.

Funding in 2010–11

Land Protection Fund ($129 000)

Collaborators

- ARC-PPRI, South Africa
- CABI Europe–UK, United Kingdom
- Centre for Origin Research, United States
- CSIRO Plant Industry
- CSIRO Ecosystem Sciences
- DERM
- Office of Environment and Heritage, New South Wales
- New South Wales Government Department of Primary Industries
- The University of Queensland
- Local governments in Queensland and New South Wales

More information

Key publications

Day, MD & Nahrung, HF 2010, 'Preference and performance of *Aconophora compressa* Walker (Hemiptera: Membracidae) on different lantana phenotypes in Australia', *Australian Journal of Entomology* 49(4): 363–8.

Day, MD, Riding, N & 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): 627–37.

Day, MD & Zalucki, MP 2009, '*Lantana camara* Linn. (Verbenaceae)', in R Muniappan, GVP Reddy & A Raman (eds), *Biological control of tropical weeds using arthropods*, Cambridge University Press, Cambridge, pp. 211–46.

Zalucki, MP, Day, MD & Playford, J 2007, 'Will biological control of *Lantana camara* ever succeed? Patterns, processes & prospects', *Biological Control* 42(3): 251–61.

Day, MD, Broughton, S & Hannan-Jones, MA 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, MD, Wiley, CJ, Playford, J & Zalucki, MP 2003, *Lantana: current management status and future prospects*, Australian Centre for International Agricultural Research, Canberra, 128 pp.

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

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

Project dates

July 2006 – June 2012

Project leader

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Objectives

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

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

Rationale

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

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 for agent establishment, population increase, spread and impact on mikania vine.

Progress in 2010–11

Mass-rearing and field-release of *P. spegazzinii* in both Fiji and Papua New Guinea continued throughout 2010–11. In Papua New Guinea, the rust was released at nearly 300 sites in 12 provinces in which the presence of mikania vine is confirmed. Pustules have now persisted on field plants at more than 120 sites in 10 provinces and some pustules have been found more than 30 km from the point of release after 12 months. It is still too early, or the sites are too distant, to confirm establishment at many of the other sites.

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

Photo 16.1 Jenitha Fidelis from the Cocoa and Coconut Research Institute, Papua New Guinea, showing rust-infected mikania to villagers in East New Britain Province, Papua New Guinea

Photo 16.2 Rust pustules on mikania vine in East New Britain Province, Papua New Guinea

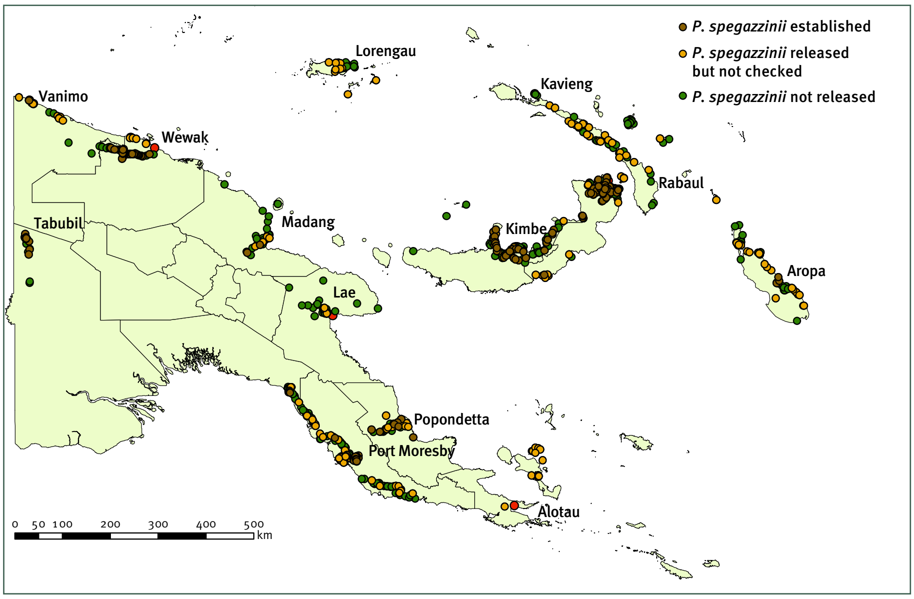

Figure 16.1 Current distribution of mikania vine and *P. spegazzinii* in Papua New Guinea

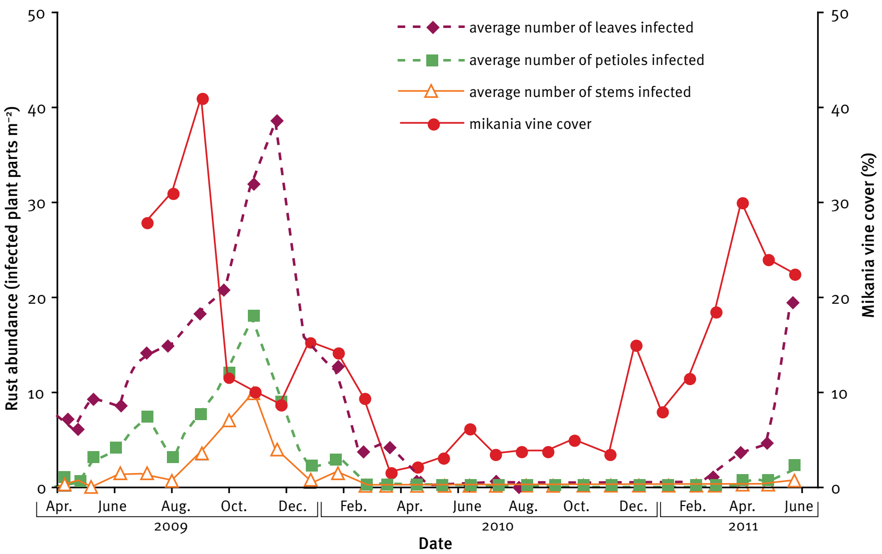

Figure 16.2 Effect of *P. spegazzinii* on mikania vine cover in an experimental plot at Kerevat, Papua New Guinea

Funding in 2010–11

Australian Centre for International Agricultural Research ($70 000)

Collaborators

- Australian Centre for International Agricultural Research
- Secretariat of the Pacific Community
- Ministry of Primary Industries, Fiji
- National Agricultural Research Institute, Papua New Guinea
- Cocoa and Coconut Research 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

Ellison, C & Day, M 2011, 'Current status of releases of *Puccinia spegazzinii* for *Mikania micrantha* control', *Biocontrol News and Information* 32(1): 1N–2N.

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Pene, S, Orapa, W & Day, M 2007, 'First9 fungal pathogen to be utilized for weed biocontrol in Fiji and Papua New Guinea', *Biocontrol News and Information* 28(3): 55N–56N.

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

17. Weed eradication and containment: feasibility and program evaluation

Project dates

July 2003 – June 2013

Project leader

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Other staff in 2010–11

Simon Brooks and Shane Campbell

Objectives

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

Rationale

Early intervention is the most cost-effective means of 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).

In previous research we have developed measures for evaluating eradication progress with regard to the delimitation (determining the extent of the incursion) and extirpation (local extinction) criteria. We also have developed dynamic models that provide estimates of eradication program duration (and total program costs when economic data is available).

Research conducted worldwide over the past decade has shown that the circumstances under which weed eradication can be achieved are highly constrained, suggesting that eradication may not be widely applicable as a weed-invasion management strategy. However, if a weed is sufficiently serious to consider eradication there may often be a strong justification for attempting to slow its spread (partial containment) should eradication prove impossible. As some weeds may be more readily contained than others, it is important to better define the scope for partial containment.

Ongoing eradication and containment feasibility work should contribute to management decisions. Case-study data is needed to determine to what degree management objectives have been achieved and to assess progress towards eradication or containment.

Methods

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 includes method of detection, discovery over time, trends in infested areas, population decline and time since last detection.

Research on assessing the feasibility of containment has adopted both qualitative and quantitative approaches.

Progress in 2010–11

'Four tropical weeds' database

We are currently converting the eradication progress reporting units from a buffered infestation area to fixed management areas of 1 ha (100 m × 100 m). This transition has been accompanied by more intense recording of plant presence and absence and will enable more consistent and accurate reporting from year to year over fixed areas. The transition will also enable portions of infestations to progress to a monitoring stage and improve the progression factors for large infestations, including the melastome species known only at single locations. A finer scale of recording and reporting can also increase the discovery rate of management areas in the short term and increase the rate of reversion (from monitoring to control status). Eventually, this new spatial regime will enable field crews to target searching to areas potentially containing plants resulting from abiotic dispersal, such as wind and water, rather than relying on large generic dispersal buffers.

Assessing feasibility of containment

The reduction of seed production in weed infestations is likely to play an important part in containment. However, this is the case for virtually all weeds and hence not a particularly discriminating feature for assessing the feasibility of containment. Therefore, our research has focused on the fates of seeds that are produced. That is, while management interventions can reduce propagule production (fecundity control) in source populations, weed spread can also be reduced through actions that interfere with dispersal and establishment, and/or lead to the detection and control of new infestations. Undetected new infestations may reproduce and give rise to further dispersal (shown as the dotted line in Figure 17.1).

Three case studies have been used in initial qualitative assessments of the feasibility of containment (Figure 17.2). The distance of dispersal affects feasibility of containment, but the ability to predict where seeds are deposited is also important, since this influences both the potential for detection of new infestations and the effort required to do so. Branched broomrape (*Orobanche ramosa*, a parasitic annual weed targeted for eradication in South Australia) is considered most containable, since its dispersal is mainly human-mediated and can be traced. Parthenium is similar, but its seeds can be dispersed widely by floodwaters, so new infestations could be more difficult to find. The feasibility of containment of miconia is considered lowest, since it is dispersed primarily by birds in relatively unpredictable directions.

Quantitative assessment of the feasibility of containment is based on a model that includes the area that must be searched, the effort required to detect a weed within this area and the potential for colonisation and establishment in sites where foci of infestation are unlikely to be detected.

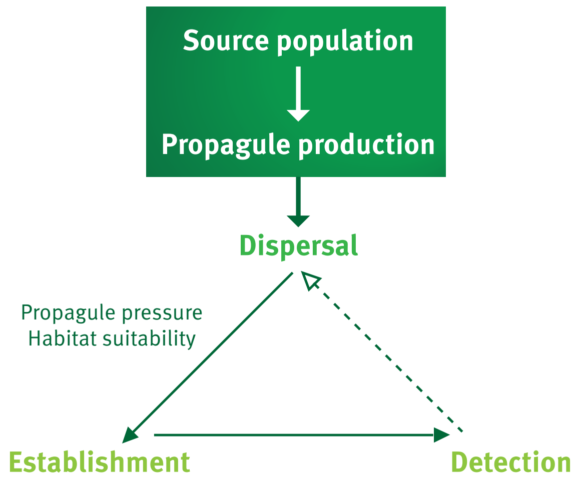

Figure 17.1 Schematic diagram showing the dispersal–establishment–detection cycle

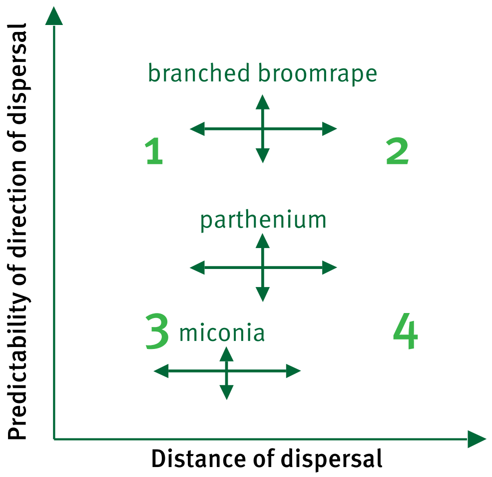

Figure 17.2 Feasibility of weed containment as influenced by combinations of distance and predictability of direction of dispersal events, with basic scenarios ranked 1–4 in order of decreasing feasibility of containment, and showing relative positions of case study species along with potential variability in each dimension

Funding in 2010–11

Queensland Government

Collaborators

- Oscar Cacho (University of New England)
- Biosecurity Queensland (South Johnstone) and local government staff—provided data for eradication case studies

More information

Key publications

Panetta, FD, Csurhes, SM, Markula, A & Hannan-Jones, MA 2011, 'Predicting the cost of eradication for 41 Class 1 declared weeds in Queensland', *Plant Protection Quarterly* 26(2): 42–6.

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

18. Ecology and control of national weed eradication targets

Project dates

July 2008 – June 2013

Project leader

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Other staff in 2010–11

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

Objectives

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

Rationale

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

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

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

Methods

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

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

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

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

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

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

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

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

- All national weed eradication target species occur along creek lines. In a seed immersion trial in the ecology laboratory at CWTA, we compare the seed viabilities of *L. flava, C. hirta, M. calvescens* and two seed collections of Siam weed immersed for 2–126 days in creek water, sea water and a 50/50 mix. Results will provide baseline data for models of aquatic dispersal. We also conduct laboratory investigations into seed buoyancy and seed germination under increasing levels of salinity.

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

- Soil cores are collected regularly from an area with a high density of *M. calvescens* (prior to control) at the El Arish infestation. Seed bank studies for *L. flava* are continuing at an infestation in a constantly wet, spring-fed, lowland tropical stream near Feluga. This data will guide the duration of control and monitoring activities, as there is no other information available on limnocharis seed persistence. All soil samples are sieved to remove, count and germinate seed.
- We also bury *C. hirta* and *M. calvescens* seed in permeable mesh packets to investigate the effects of burial duration and depth in a wet tropics environment at CWTA. Packets are retrieved every 6–24 months until no viable seed is recovered.

Progress in 2010–11

Siam weed—age to maturity

At TWRC all of the Siam weed plants raised from Townsville seed in late October, November and December 2009 flowered in May 2010. Also, 5 out of 6 plants raised from seed in late January 2010 flowered in late May and were destructively harvested. All remaining plants sown monthly until October 2010 flowered in May 2011. Some plants from three additional treatments sown fortnightly from mid-January 2011 also commenced flowering in May 2011.

In the wet tropics trial, 6 out of 18 plants raised from seed between early November 2009 and mid-January 2010 flowered in May 2010. All remaining plants that were sown monthly until November 2010 flowered in early May 2011.

Both trials show that under ideal (pot) conditions, Siam weed can be raised from seed between November and January and flower by June. It is not yet known how often plants would flower so quickly under field conditions. However, both trials highlight the importance of effectively surveying and controlling infestations between early February and flowering in May/June. Flowering plants varied in size depending on their age, so this trial illustrates that the time to flower bud initiation is driven by day length.

Siam weed—seed longevity

Seeds were buried in December 2009. We recorded a mean seed viability of 72% at the beginning of the trial. Considerable germination was noted in surface-situated bags during the wet season and seed viability averaged 23% after 6 months and 12.5% after 12 months across all burial depths. Viability after 12 months of surface seed, seed buried at 3 cm and seed buried at 13 cm was 4.1%, 15.6% and 17.9% respectively. We are currently assessing seed retrieved after 18 months.

Siam weed—fire response

For monitoring results following the first controlled burn in October 2008, see *Technical highlights 2008–09* and *Technical highlights 2009–10*. Controlled burns were not conducted in the following two years due to dangerously dry conditions in 2009 and wet conditions in 2010. In June 2011, we completed pre-burn assessments and conducted a second controlled burn shortly after.

Siam weed—splatter gun trials

For results from the first trial in March 2009, see *Technical highlights 2009–10*. A second trial in April 2010 demonstrated that lower rates of two fluroxypyr-based herbicides were also effective. In May 2010, we conducted a third trial to verify the effectiveness of lower rates of fluroxypyr compared to higher rates of metsulfuron-methyl. Results are pending.

Seed immersion trials

Results of the seed immersion trial demonstrated that 126 days of immersion in any of the three water types tested is not a barrier to the dispersal of viable seed for all four species included in this trial. However, further trials have shown that Siam weed seed will not survive when it is maintained in solutions containing more that 250 mmol of sodium chloride and *M. calvescens* seedlings will not establish in solutions containing more than 100 mmol of sodium chloride. So although seed can be dispersed by sea or brackish water, highly saline environments are not suitable habitats for plant establishment.

Miconia calvescens*—seed bank persistence*

Sampling of the soil seed bank at El Arish shows that small numbers of seedlings continue to emerge and there has been no decline in the density of seed extracted from the soil.

We also established a buried seed trial in October 2010. Prior to burial, over 80% of seed was viable. We are currently assessing seed retrieved after 6 months.

Limnocharis*—seed bank persistence*

Monitoring between 2003 and 2009 has shown no notable decline in viability or seed density of limnocharis in the soil seed bank at a site near Feluga (Table 18.1), even though seed input has not been recorded since 2004 and the number of plants emerging at the infestation has declined over this period. However, sampling in 2010 has detected a marked reduction in seed density (Table 18.1).

Additional research

In 2011, Siam weed leaf samples were collected from Townsville and wet tropics infestations and from a smaller, phenotypically different Siam weed infestation near Tully. Collaborator Dr Jane Oakey used the leaf samples to develop a specific test for low concentrations of *C. odorata* DNA of both phenotypes. This investigation may lead to the use of water sampling to determine whether Siam weed is locally present or absent.

A small trial was established in collaboration with CSIRO Ecosystem Sciences to measure the monthly emergence, survival and growth of *M. racemosa* plants in the field. More than 80% of seed obtained from a *M. racemosa* plant in the field has been found to be viable and plants from these are currently raised to enable observations of age to maturity under controlled conditions.

Funding in 2010–11

- Queensland Government
- National Siam Weed Eradication Program and Four Tropical Weeds Eradication Program, through national cost-share arrangements ($60 000)

Table 18.1 Number, distribution and viability of *L. flava* seeds extracted from 40 mud samples collected between 2003 and 2010 at an infestation near Feluga, northern Queensland

Year	2003	2005	2006	2007	2008	2009	2010
Number of seeds sieved from 40 samples	623	358	1252	489	530	323	8
Samples with seeds (%)	70.7	77.5	82	55.5	67.5	47.5	2.5
Average number of seeds per sample	15.2	9.0	31.3	12.2	13.3	8.1	0.4
Seed viability (%)	–	64.7	54.4	59.5	80.7	57.9	100

Collaborators

- Biosecurity Queensland officers based at South Johnstone and Townsville—provided assistance with locating and accessing trial areas
- DERM staff—coordinated the controlled Siam weed burn
- Dr Jane Oakey, Molecular Biologist (Biosecurity Queensland)
- CSIRO Ecosystem Sciences, Atherton
- School of Land, Crop and Food Sciences, The University of Queensland

More information

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

19. Class 1 weed control packages

Project dates

July 2008 – June 2013

Project leader

Joseph Vitelli
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Other staff in 2010–11

Barbara Madigan and Annerose Chamberlain

Objectives

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

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

Rationale

Expanding the current Queensland Class 1 plant declaration list to species level yielded a list of 8978 taxa, including hybrids, cultivars and synonyms. Restricting the list to those Class 1 species already present in Australia narrowed the total to 156, of which 53 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 is 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 resources needed to achieve eradication.

Control efforts are also hindered by a lack of chemical registrations. Of the 53 naturalised Class 1 plant species, 9 have chemical recommendations, 21 are captured under broader categories (e.g. *Acacia* spp., cacti or the Environmental Permit PER11463) and 23 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

Ecological studies

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

Control studies

We develop chemical and non-chemical control options that can be integrated into eradication programs and provide data to assist minor use applications.

Progress in 2010–11

Ecological studies

A seed library of Class 1 weeds naturalised in Queensland to date contains seeds from Mexican feather grass (*Nassella tenuissima*), Mexican bean tree (*Cecropia peltata*), trumpet tree (*Cecropia palmata*), badhara bush (*Gmelina elliptica*), mimosa (*Mimosa pigra*), Koster's curse (*Clidemia hirta*), miconia (*Miconia calvescens*), Senegal tea (*Gymnocoronis spilanthoides*), Siam weed (*Chromolaena odorata*) and *Acacia glauca*.

Field monitoring studies showed that the reproductive period for Mexican feather grass is from September to March. We have transplanted 38 seedlings of known age from the field and repotted them at the Ecosciences Precinct to determine time to reproductive maturity. To date, 16% of plants have flowered at an age of 19–23 months between August and March. Studies are ongoing.

Although their flowering was prolific, water mimosa (*Neptunia oleracea*) failed to produce seed at the Alan Fletcher Research Station, Ecosciences Precinct and TWRC, delaying planned seed studies. To resolve *Neptunia* identification problems in Queensland, *N. oleracea* and *N. plena* DNA samples were sought from the New York Herbarium and the Kew Royal Botanic Gardens Herbarium. Molecular probes for these two species have now been developed by Dr Jane Oakey.

Eight additional *Cecropia* sites have been found in northern Queensland. Growth scars indicate that some plants are more than 20 years old. At a Clifton Beach location, three separate cohorts have established, with plant height ranging from 1.3 to 14 m. Morphological traits indicate at least three *Cecropia* species have established in northern Queensland. We have collected leaf samples from most sites and have stored them for future DNA analysis.

Accelerated seed ageing trials have been initiated for Senegal tea, Siam weed, *Acacia glauca*, Koster's curse, miconia and badhara bush. Germination/viability testing is ongoing.

Control studies

An alligator weed (*Alternanthera philoxeroides*) herbicide trial at Bullock Head Creek using glyphosate at two and three times the recommeneded rate appears to have been effective. The dense stand of alligator weed along 1 km of the creek has been reduced to isolated plants totalling less than 2 m^2.

A foliar spray screening trial involving five herbicides was initiated on Senegal tea growing at a Strathpine trial site in April 2011.

Class 1 minor use permit

A draft minor use permit capturing all Queensland Class 1 declared weeds is now complete. The final version will be submitted to APVMA by May 2012.

To assist Class 1 eradication efforts, we obtained new minor use permits for control of gingers (*Hedychium* spp.), PER12436, and tussock grasses (*Nassella* spp.), PER12202. (For details, see project report 34 on page 76.)

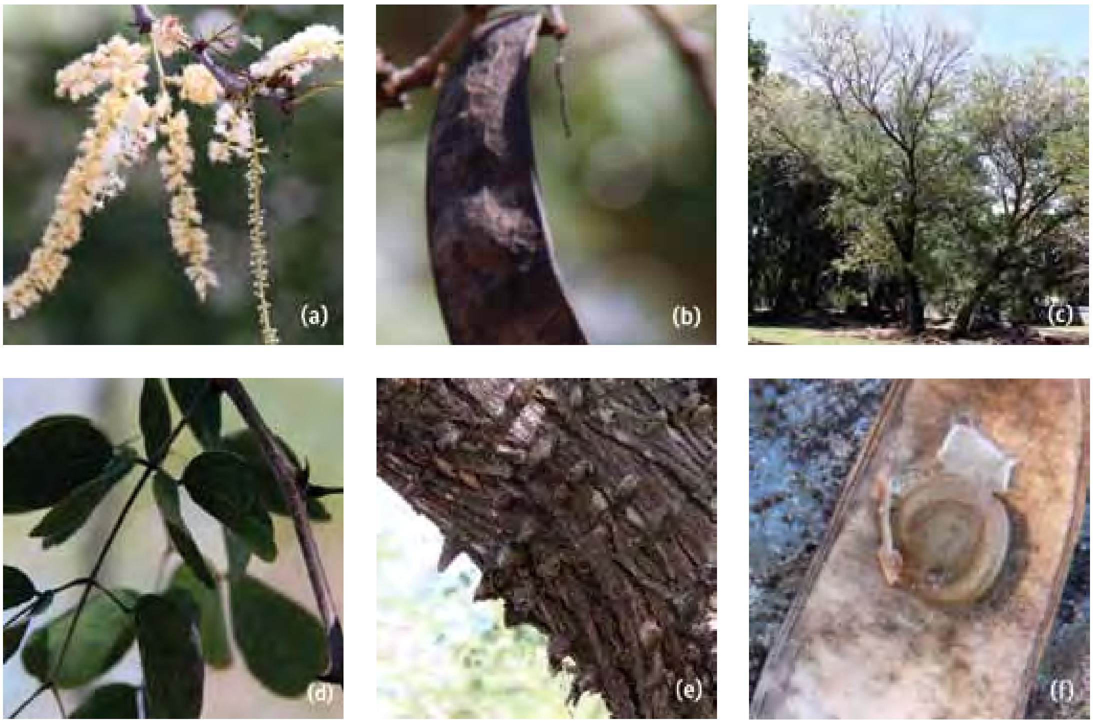

Photo 19.1 (a) Inflorescence, (b) pod, (c) adult tree, (d) leaves, (e) trunk and (f) seed of *Acacia pringlei*, a newly detected non-indigenous acacia species; all non-indigenous *Acacia* species are Class 1 declared weeds in Queensland

Funding in 2010–11

Queensland Government

Collaborators

- Dr Jane Oakey, Molecular Biologist (Biosecurity Queensland)
- Biosecurity Queensland field staff
- Brisbane City Council
- Capricorn Pest Management Group
- Logan City Council
- Seqwater

More information

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

20. *Mimosa pigra* research

Project dates

July 2008 – June 2013

Project leader

Joseph Vitelli
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Other staff in 2010–11

Barbara Madigan

Objectives

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

Rationale

Mimosa pigra is a WONS and a Class 1 declared weed in Queensland. Originating from Central America, *M. pigra* poses a major threat to the integrity of northern Australia's wetlands, reducing biodiversity and affecting primary production. In the Northern Territory it has formed impenetrable, nearly mono-specific thickets over 800 km². In February 2001, the first infestation of *M. pigra* in Australia outside the Northern Territory was found at Peter Faust Dam, near Proserpine in central coastal Queensland. A stakeholder group was formed to eradicate the infestation. One of Biosecurity Queensland's contributions is to provide research on the biology and control of *M. pigra* to aid in the eradication effort. This includes advising on the timing of site revisits to ensure plants are detected and controlled prior to setting seed, and predicting how long the eradication effort needs to continue.

Methods

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

Seedling emergence and seed bank

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

Molecular studies

Next-generation (whole-genome) sequencing of *M. pigra* DNA is undertaken by the Australian Genome Research Facility using the 454 sequencing system. Then Dr Jane Oakey uses up to 150 microsatellite loci for *M. pigra* to determine alleles from *M. pigra* infestations in Queensland and Western Australia and from 20 reference populations in the Northern Territory.

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

Progress in 2010–11

Seedling emergence and seed bank

Soil cores were not extracted during 2010–11, as the core area remains inundated as a result of the heavy rains in early 2010.

Molecular studies

We isolated 215 polymorphic microsatellite markers from an enriched library of *M. pigra* genome DNA and used 76 of these microsatellite loci to screen 234 samples from Australia, Africa, North, Central and South America, and the Asia–Pacific region.

The level of homogeneity found within the Australian samples was high, suggesting that a low level of genetic diversity exists for this species within Australia. This implies that there might have been only a single introduction of *M. pigra* into Australia. Results from the neighbour-joining tree analysis indicate that the Australian population cluster may be related to the cluster containing specimens from Brazil and one region in Mexico (Guerrero, San Marcos). Further specimens will need to be examined before any credence is given to this relationship. The work is ongoing.

Funding in 2010–11

Queensland Government

Collaborators

- Dr Jane Oakey, Molecular Biologist (Biosecurity Queensland)
- Kay Bailey, National WONS Coordinator for *M. pigra* and athel pine, and Christopher Collins, Bert Lukitsch, Ian Cowie, Ben Stuckey, Em Pedler and Ben Matthias (NRETAS, Northern Teritory)
- Tim Heard and Gio Fichera (CSIRO Ecosystem Sciences)
- Chris Hawkins and Tracey Vinnicombe (Department of Agriculture and Food, Western Australia)
- Syd Laker (Adjumarllarl Rangers)
- Willy Rioli, Vivian, Kim, D. Tipakalippa, Colin and Nicholas Hunter (Tiwi Land Council, Pirlingimpi Community)

More information

Key publication

Vitelli, JS, Madigan, BA & Worsley, KJ 2006, '*Mimosa pigra* in Queensland', in C Preston, JH Watts and ND Crossman (eds), *Proceedings of the 15th Australian Weeds Conference*, Weed Management Society of South Australia, Adelaide, pp. 251–4.

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

21. Ecology and control of wet tropics weeds

Project dates

January 1999 – June 2013

Project leader

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Other staff in 2010–11

Stephen Setter, Katie Patane, Wayne Vogler, Laura Roden and Barbara Madigan

Objective

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

Rationale

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

Methods

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

Pond apple mechanical control

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

Navua sedge

We conduct a foliar herbicide screening trial near Millaa Millaa on the Atherton Tableland and we use the results to determine the next phase of herbicide trials. The aim is to develop effective selective herbicide options for navua sedge control in sown tropical pastures and non-agricultural areas.

Bog moss

We undertake field trials in a small drain infested with bog moss to provide control options for this emerging aquatic weed. Treatments include the use of herbicides (UniMaz 250™ 4 L ha^{-1} with Bonus™ wetter 1.5 L ha^{-1}) as well as shadecloth (92% light reduction) and black plastic (for more sensitive environments).

We also conduct a herbicide screening trial in the glasshouse, in which 10 herbicides (triclopyr, endothal, glyphosate, imazapyr, metsulfuron, dichlobenil, flumioxazin, bispyribac, carfentrazone and diquat + guar gum) are added at two rates to submerged bog moss growing in 2 L jars. The most effective herbicides are then tested in a rates trial in jars and in a large container trial with emergent bog moss.

Progress in 2010–11

Pond apple mechanical control

We have established transects and applied the mechanical control treatments; monitoring and analysis are ongoing (Table 21.1). Very wet conditions prevented access, so we could not control regrowth as planned. Fruiting has been observed on resuckering trees 18 months after treatment.

Photo 21.1 Stephen Setter applying herbicides to a navua sedge plot as part of initial screening trials

Table 21.1 Area treated, cost and efficacy of the Positrack™ and Tracksaw™ machines in controlling pond apple and regrowth 12 months after treatment

	Positrack™	Tracksaw™
Area treated in 2 days (ha)	1.5	0.75
Initial pond apple density (plants ha^{-1})	11 000	3 300
Mortality—mechanical control only (%)	83	n/a
Mortality—mechanical + herbicide control (%)	95	90
Treatment cost ($ ha^{-1})	2 300	2 730
Regrowth 12 months after treatment (seedlings ha^{-1})	2 600	18 500

Table 21.2 Herbicide efficacy on navua sedge in the foliar spray screening trial at Millaa Millaa 2010

Treatment[a]	Active ingredient	Product application rate	Live stems (% of baseline)		
			42 days after treatment	84 days after treatment	140 days after treatment
Control	–	–	140	113	200
Sempra™	halosulfuron	130 g ha^{-1}	60	103	236
Sempra™ + Roundup 360™	halosulfuron + glyphosate	130 g ha^{-1} + 3 L ha^{-1}	37	37	81
Sempra™ + Amicide 625™	halosulfuron + 2,4-D amine	130 g ha^{-1} + 3.2 L ha^{-1}	56	143	232
Sempra™+ Amicide 625™ + Kamba 500™	halosulfuron + 2,4-D amine + dicamba	130 g ha^{-1} + 3.2 L ha^{-1} + 1.44 L ha^{-1}	37	81	167
Sempra™ + Amicide 625™ + Liase™	halosulfuron + 2,4-D amine + ammonium sulphate	130 g ha^{-1} + 3.2 L ha^{-1} + 28.8 L ha^{-1}	50	115	223
Sempra™ + Agritone™	halosulfuron + MCPA amine	130 g ha^{-1} + 2.67 L ha^{-1}	64	154	314
NUL2452[b]	NUL2452	130 g ha^{-1}	45	62	178
NUL2452 + LVE[c] Agritone™	NUL2452 + LVE MCPA	130 g ha^{-1} + 1.75 L ha^{-1}	47	78	208
NUL2452 + Roundup 360™	NUL2452 + glyphosate	130 g ha^{-1} + 3 L ha^{-1}	47	25	79
Amicide 625™ + Kamba 500™	2,4-D amine + dicamba	3.2 L ha^{-1} + 1.44 L ha^{-1}	82	118	225
Amicide 625™	2,4-D amine	3.2 L ha^{-1}	84	117	181
Arsenal Express™	imazapyr + glyphosate	7 L ha^{-1}	40	18	48
Flame™	imazapic	1 L ha^{-1}	68	121	268
Flame™ + Roundup 360™	imazapic + glyphosate	1 L ha^{-1} + 3 L ha^{-1}	46	23	151
Midas™	MCPA + imazapic + imazapyr	4 L ha^{-1}	82	256	305
Arsenal 250™	imazapyr	4 L ha^{-1}	46	63	154

a Pulse adjuvant has been added to all herbicides at 2 mL L^{-1}.

b NUL2452 is a Nufarm experimental product.

c LVE = low-volatility ester.

Navua sedge

The foliar herbicide screening trial has been completed. No herbicide treatment adequately controlled navua sedge. All herbicides reduced the number of navua sedge live stems at 42 days after treatment. These numbers had increased at 84 days after treatment in all treatments except those containing glyphosate, in which live stems continued to decline. However, at 140 days after treament, live stem numbers increased in all treatments, with those not containing glyphosate showing consistently more than 150% of the baseline value (Table 21.2).

Although treatments containing glyphosate were the most effective, they are not selective and therefore not suitable for use in grass-based pasture systems and other non-agricultural situations where selective herbicides are required. Future research will focus on Sempra™ and Sempra-based herbicide mixes, including split herbicide application in combination with pasture management practices. Other herbicides will be screened for efficacy as necessary.

Bog moss

In the field trials, estimated biomass reduction 120 days after treatment for the herbicide, black plastic and shadecloth treatments were 100%, 100% and 95% respectively.

For the herbicide screening trial, we made final assessments at 120 days after treatment. We will now test the six most effective herbicides (triclopyr, endothal, diquat + guar gum, metsulfuron, fumioxazin and carfentrazone) at four rates each in a rates trial.

Funding in 2010–11

- Land Protection Fund ($62 000)
- Queensland Government

Collaborators

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

More information

Key publications

Westcott, DA, Setter, MJ, Bradford, MG, McKeown, A & 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): 432–9.

Mason, LB, Setter, MJ, Setter, SD, Hardy, T & Graham, MF 2008, 'Ocean dispersal modelling for propagules of pond apple (*Annona glabra* L.)', in RD van Klinken, VA Osten, FD Panetta & JC Scanlan (eds), *Proceedings of the 16th Australian Weeds Conference*, Queensland Weeds Society, Brisbane, Queensland, pp. 519–21.

Setter, SD, Setter, MJ, Graham, MF & Vitelli, JS 2008, Buoyancy and germination of pond apple (*Annona glabra* L.) propagules in fresh and salt water', in RD van Klinken, VA Osten, FD Panetta & JC Scanlan (eds), *Proceedings of the 16th Australian Weeds Conference*, Queensland Weeds Society, Brisbane, Queensland, pp. 140–2.

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

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

Project dates

July 2008 – June 2012

Project leader

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Other staff in 2010–11

Christine Perrett and Cameron Clark

Objectives

- Use size-structured population matrices and mathematical models to examine vital rates of growth, reproduction and survival of lantana under various landscape scenarios 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.
- Analyse spatio-temporal changes in stand dynamics of lantana to explore better management of the weed.

Rationale

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

Methods

We set up and census permanent plots of 50 m × 50 m at each of four infested sites in the Yarraman–Blackbutt area west of Brisbane (Photo 22.1) to determine the parameters of lantana's vital rates (seed germination and dormancy, seedling, juvenile and adult growth and survival, and adult fecundity) for projection of its population growth. We also use spatial analytical techniques to assess first-order and second-order spatial patterns of established individuals and recruits.

The four field sites (hoop pine plantation, natural forests subject to either periodic burning or grazing regimes, and cattle property) contain, in increasing order, low to moderate infestations of lantana, but differ in soil properties, rainfall intensity, land use type and weed control practices.

Progress in 2010–11

The third and final census of population dynamics across the four field sites—consisting of more than 2000 permanently tagged lantana plants—was completed. We are now using census data to explore spatio-temporal variation in stand dynamics, spatial patterns and population growth of the weed.

Populations at most sites exhibited plant height and crown size distributions that are L-shaped, J-shaped or symmetrical and thus unimodal. Bimodality was observed at the farm site only; this suggests that two distinctive cohorts exist (Figure 22.1). Relative growth rate of lantana plants at the farm site was not influenced by size. This contrasts significantly with trends observed in the other three sites, where one-sided (size asymmetric) growth and competition were apparent.

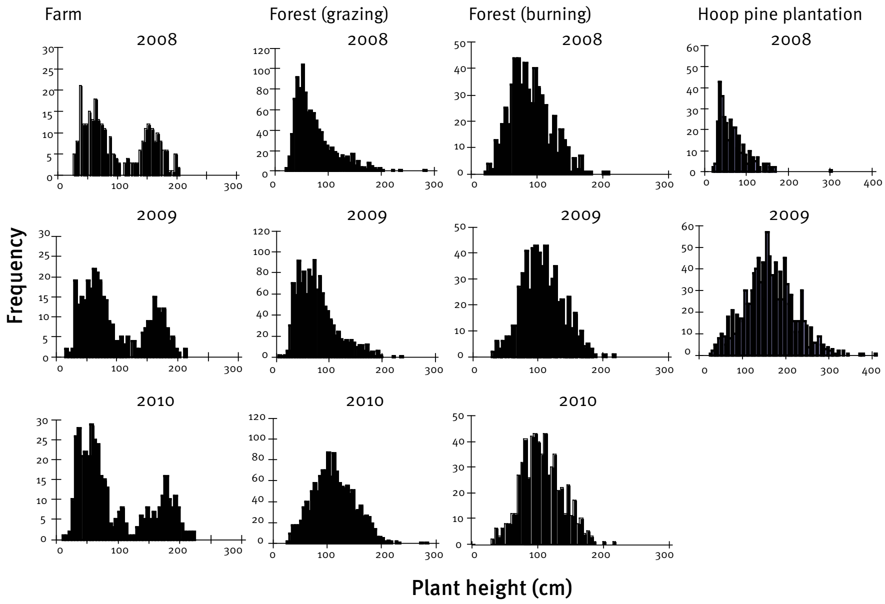

Figure 22.1 Changes in lantana plant height distribution in each of the four populations surveyed over three years: note that the *y*-axis (frequency) scale varies between sites

Spatial pattern analyses indicated that established and newly recruited individuals are aggregated and that the degree of aggregation decreases with plant size. However, after fire, seedling and juvenile recruitment assume negative association (spatial displacement/decoupling) in relation to established individuals, perhaps in response to increased lantana litter (fuel load) and thus more intense temperature build-up around existing parent plants during burning. This finding implies that in a landscape where burning is used as a management tool, any follow-up with herbicide that focuses on reducing recruitment can simply concentrate on spaces between established individuals, thereby reducing both herbicide and labour cost.

Density and plant size had appreciable effects on the weed's reproductive capacity and growth, but surprisingly not on survival. The trends in fruit production as a function of plant height were statistically significant at $p < 0.05$. The intercept but not the slope differed significantly ($p < 0.05$) between populations (Figure 22.2).

On average, lantana populations exhibit reproductive activity at least twice per year, and even more in a good season, when resources (especially moisture) are adequate (Figure 22.3). The lantana population at the hoop pine plantation could only be followed in the first 10 months of the survey due to closing of the canopy and the impenetrable thicket that then developed.

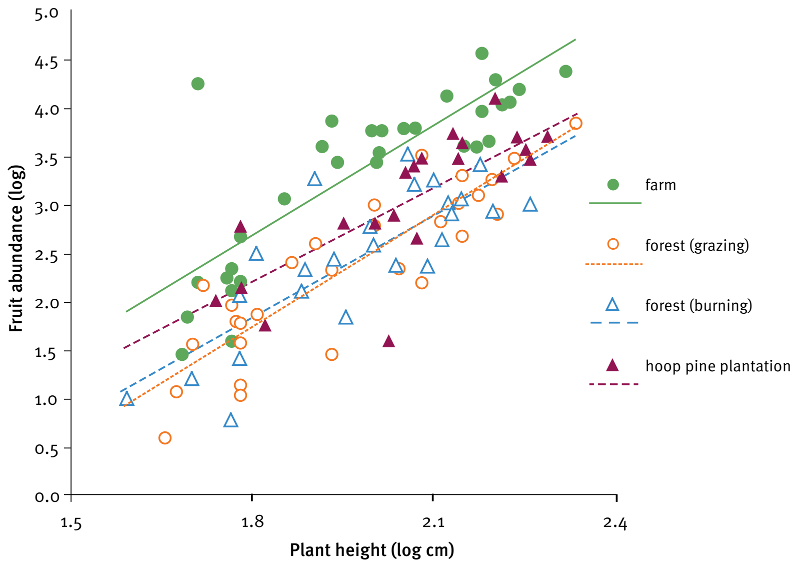

Figure 22.2 Lantana fruit production in 2008 as a function of plant height in the four populations surveyed

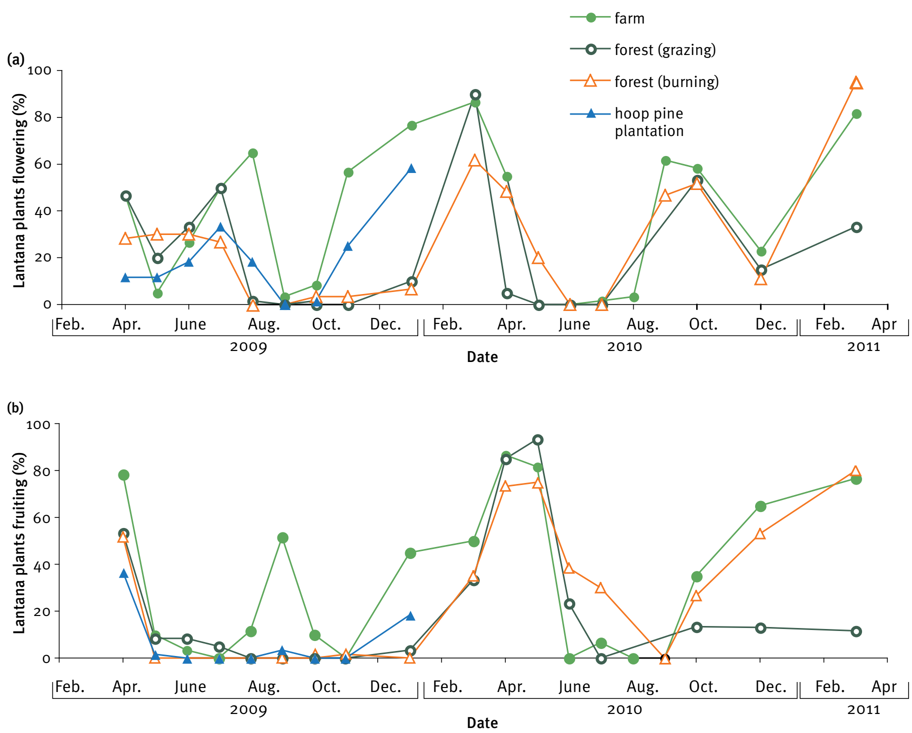

Figure 22.3 Pattern of (a) flowering and (b) fruiting of lantana over two years in the four populations surveyed

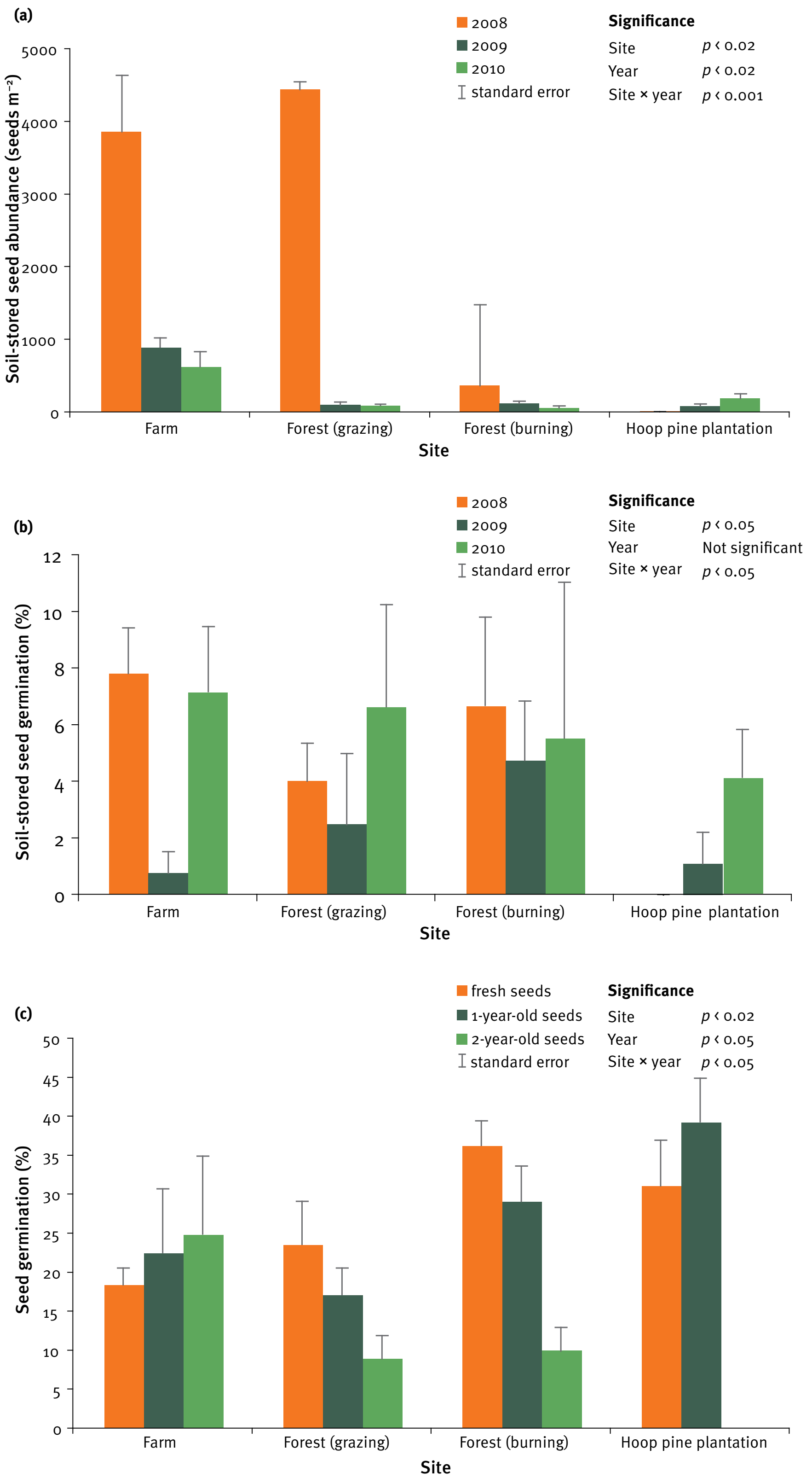

Figure 22.4 Seed trait dynamics of lantana in each of the four populations surveyed: (a) soil-stored seed abundance, (b) soil-stored seed germination and (c) seed germination in relation to time since soil burial

Periodic but slow/moderate burning of a lantana infestation as a management tool appears not to tilt the population to negative growth, although it can reduce soil-stored seed viability and abundance (which can be as high as 1000 seeds m^{-2}). Approximately 25% of fresh lantana seeds remain viable even after three years of burial, confirming that seed persistence of the weed can be long (Figure 22.4).

Environmental variability is the norm rather than the exception. Over three years, our surveys across varying landscape and land-use types have enabled us to capture such variability. The next task is to build robust population growth models and then combine the demographic information collected with economic data (e.g. control cost per plant or per hectare) and environmental data (e.g. long-term rainfall trend). This will lead to better informed decisions on the feasibility of local control/eradication of the weed.

Funding in 2010–11

- Queensland Government
- Land Protection Fund ($37 000)

Collaborators

- S. Raghu (CSIRO Ecosystem Sciences, Brisbane)
- Joe Scalan (Biosecurity Queensland, Toowoomba)

More information

Key publication

Osunkoya, OO, Perrett, C & Fernando, C 2010, 'Population viability analysis models for *Lantana camara* L. (Verbenaceae): a weed of national significance', in SM Zydenbos (ed.), *Proceedings of the 17th Australasian Weeds Conference*, New Zealand Plant Protection Society, Christchurch, New Zealand, pp. 99–102.

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

23. Impacts of environmental weeds on soil processes

Project dates

January 2010 – June 2012

Project leader

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Other staff in 2010–11

Christine Perrett and Cameron Clark

Objective

Document the impacts of environmental weeds on soil processes.

Rationale

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

Methods

At eight cat's claw creeper field sites of varying habitat and land-use type in the Brisbane – Gold Coast region, we sample:

- surface active (epigaeic) and subterranean soil (hypogaeic) ants in infested and uninfested areas spanning both riparian and non-riparian habitats to investigate patterns of ant species composition and functional grouping in response to patch invasion status, landscape type and habitat stratum
- soil beneath and away from established cat's claw creeper patches (4 samples per site) to document the likely effect of the weed on 23 soil physicochemical properties
- leaves of cat's claw creeper and co-occurring native vines (*Parsonsia straminea* and *Smilax australis*) and introduced but low-impact vines (corky passionfruit, *Passiflora suberosa*) to explore differences in leaf chemistry between invasive and non-invasive species.

Collected data is then subjected to univariate as well as multivariate ordination techniques.

Progress in 2010–11

Invasion effect on soil ant assemblage

The epigaeic and subterranean strata supported markedly different ant assemblages, and ant communities also differed between riparian and non-riparian habitats. However, cat's claw creeper invasion had a limited impact. There was a tendency for ant abundance and species richness to be lower in infested patches, and overall species composition was different between infested and uninfested patches, but these differences were relatively small, and did not occur consistently across sites.

Our study has shown that ant communities are surprisingly resilient to invasion by cat's claw creeper, and serves as a warning against making assumptions about invasion impacts based on visual appearances. A paper detailing research findings has been published in *Biological Invasions* (Osunkoya et al. 2011).

Invasion effect on soil physicochemical properties

A significant site effect was more frequently observed than an effect due to invasion status. Nonetheless, after controlling for site differences, about 50% of the 23 soil traits examined differed significantly between infested and non-infested soils (Table 23.1).

In soils supporting cat's claw creeper, the following were significantly elevated: moisture, pH, calcium, organic carbon (OC), total carbon (TC), total nitrogen (TN) [but not exchangeable nitrogen in the form of ammonium or nitrate], magnesium, sulfur, chloride and electrical conductivity (EC). Exchangeable sodium and iron (which can be toxic to plant growth if present in excessive levels) were present at lower levels (Figure 23.1). These results indicate that cat's claw creeper—like lantana (see *Technical highlights 2009–10* and Osunkoya & Perrett 2011)—can improve soil fertility and influence nutrient cycling, making the substratum ideal for its own growth. This might explain the ability of the weed to out-compete other species, especially native ones.

Leaf chemistry of cat's claw creeper v. non-invasive species

As for the soil data, leaf chemistry of cat's claw creeper and non-invasive species varied more across survey sites than between invasion status (Table 23.2). Nonetheless, following removal of the site effect, about 75% of nutrients tested in cat's claw creeper were significantly different from those in low-impact introduced vines. Cat's claw creeper leaves possess more nitrogen, phosphorus, potassium, aluminium, boron, cadmium, cobalt, copper, iron and molybdenum but significantly less calcium, magnesium and manganese than the other vines. This trend of higher nutrient load (especially nitrogen, phosphorus and potassium) for cat's claw creeper is in line with invasive plants' preference for disturbed habitats commonly associated with high pulses of nutrient input. Calcium has been implicated in formation of oxalate crystals in leaves for defence. The significantly lower level of calcium in cat's claw creeper leaves despite a higher level of this nutrient in the soil could be due to a reduced level of herbivory from natural enemies in novel environments lowering the need to accumulate defence materials.

Table 23.1 Two-way analysis of variance (ANOVA) summary results of soil physicochemical properties in patches infested with and patches not infested with cat's claw creeper across six sites in the Brisbane – Gold Coast region

	Summary ANOVA			Group mean[a] (± SE[b])	
Soil trait	**Site**	**Invasion**	**Site × invasion**	**Infested**	**Uninfested**
Air dry moisture (%)	$p \leq 0.001$	$p \leq 0.01$	NS[c]	3.16 ± 0.28	2.54 ± 0.23
Soil macronutrients					
Organic carbon (%)	$p \leq 0.001$	$p \leq 0.01$	NS	4.09 ± 0.34	3.48 ± 0.28
Total carbon (%)	$p \leq 0.001$	$p \leq 0.001$	NS	4.74 ± 0.36	3.99 ± 0.28
Total nitrogen (%)	$p \leq 0.001$	$p \leq 0.001$	NS	0.35 ± 0.03	0.28 ± 0.02
Exchangeable ions and micronutrients					
Nitrate nitrogen (mg kg^{-1})	$p \leq 0.001$	NS	NS	17.71 ± 2.10	15.17 ± 1.30
Nitrate ammonia (mg kg^{-1})	$p \leq 0.001$	NS	$p \leq 0.05$	3.10 ± 0.50	3.40 ± 0.59
Phosphorus (mg kg^{-1})	$p \leq 0.001$	NS	NS	29.38 ± 3.77	28.42 ± 5.06
Potassium (meq 100 g^{-1})	$p \leq 0.001$	NS	NS	0.73 ± 0.07	0.62 ± 0.08
Calcium (meg 100 g^{-1})	$p \leq 0.001$	$p \leq 0.05$	NS	15.69 ± 2.04	12.03 ± 1.79
Exchangeable sodium (meq 100 g^{-1})	$p \leq 0.001$	$p \leq 0.01$	NS	0.05 ± 0.01	0.09 ± 0.02
Total sodium (meq 100 g^{-1})	$p \leq 0.001$	NS	NS	0.11 ± 0.02	0.14 ± 0.02
Magnesium (meq 100 g^{-1})	$p \leq 0.001$	$p \leq 0.10$	NS	5.55 ± 0.55	4.74 ± 0.59
Copper (mg kg^{-1})	$p \leq 0.001$	NS	NS	1.29 ± 0.21	1.35 ± 0.23
Iron (mg kg^{-1})	$p \leq 0.001$	$p \leq 0.10$	NS	87.10 ± 10.12	109.64 ± 10.12
Manganese (mg kg^{-1})	$p \leq 0.001$	NS	NS	42.52 ± 7.42	41.46 ± 6.90
Zinc (mg kg^{-1})	$p \leq 0.01$	NS	NS	4.27 ± 1.12	3.47 ± 1.15
Sulfur (mg kg^{-1})	$p \leq 0.001$	$p \leq 0.10$	NS	12.54 ± 1.11	10.62 ± 1.37
Chemical characteristics					
pH	$p \leq 0.001$	$p \leq 0.01$	NS	6.23 ± 0.14	5.90 ± 0.14
Electrical conductivity (dS m^{-1})	$p \leq 0.001$	$p \leq 0.001$	NS	0.10 ± 0.01	0.07 ± 0.01
Chloride (mg kg^{-1})	$p \leq 0.01$	$p \leq 0.01$	$p \leq 0.10$	24.96 ± 0.78	18.60 ± 2.58
Soil texture					
Coarse sand (%)	$p \leq 0.001$	NS	NS	23.83 ± 1.99	24.42 ± 2.41
Fine sand (%)	$p \leq 0.001$	NS	NS	33.96 ± 2.14	35.58 ± 1.84
Silt (%)	$p \leq 0.001$	NS	NS	19.50 ± 1.48	20.08 ± 1.75
Clay (%)	$p \leq 0.001$	NS	NS	25.83 ± 1.68	23.83 ± 1.46

a Group means have been pooled across two habitats (riparian and non-riparian) and six survey sites.

b SE = standard error.

c NS = not significant.

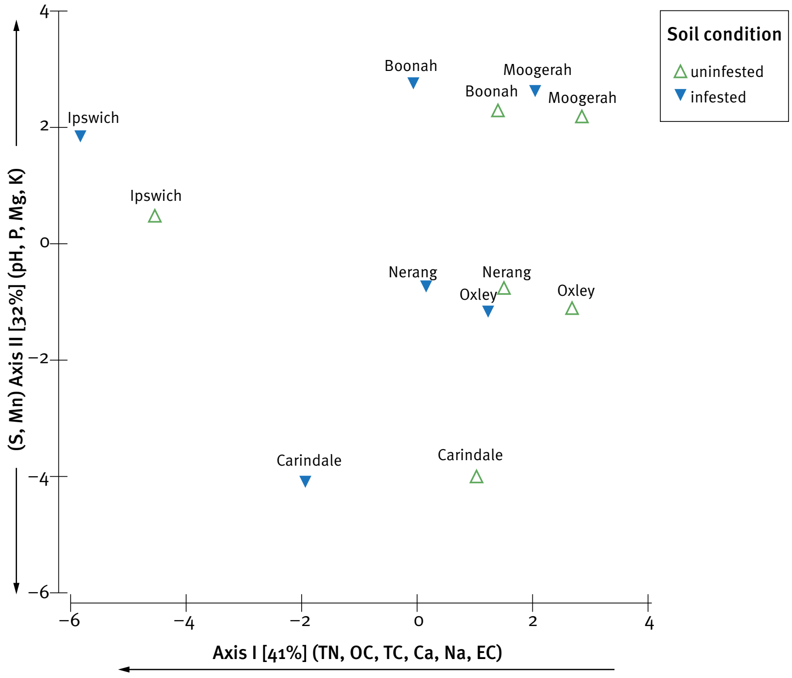

Figure 23.1 Ordination of soils underneath (closed symbols) and away from (open symbols) cat's claw creeper patches across six sites of varying land use: arrows indicate direction and magnitude of soil traits driving each axis; percentages refer to data variation captured by each axis

Table 23.2 Two-way ANOVA summary results of leaf chemistry in cat's claw creeper compared to co-occurring introduced non-invasive (*P. suberosa*) and native (*P. straminea* and *S. australis*) species across six sites in the Brisbane – Gold Coast region

	Summary ANOVA			Group mean[a] (± SE[b])	
Leaf trait	**Site**	**Invasion**	**Site × invasion**	**Invasive**	**Non-invasive**
Macronutrients (%)					
Total nitrogen	$p \leq 0.001$	$p \leq 0.001$	NS[c]	2.88 ± 0.01	2.06 ± 0.09
Total phosphorus	$p \leq 0.001$	$p \leq 0.001$	$p \leq 0.001$	0.42 ± 0.03	0.26 ± 0.02
Potassium	$p \leq 0.001$	$p \leq 0.01$	NS	2.45 ± 0.12	1.82 ± 0.11
Calcium	NS	$p \leq 0.01$	$p \leq 0.05$	1.65 ± 0.09	2.45 ± 0.24
Magnesium	NS	$p \leq 0.001$	NS	0.26 ± 0.02	0.59 ± 0.07
Sodium	$p \leq 0.001$	NS	$p \leq 0.01$	0.04 ± 0.01	0.06 ± 0.01
Sulphur	$p \leq 0.01$	NS	NS	0.19 ± 0.02	0.23 ± 0.02
Micronutrients (mg kg^{-1})					
Aluminium	$p \leq 0.05$	$p \leq 0.05$	NS	82.38 ± 9.62	56.20 ± 9.28
Boron	NS	$p \leq 0.001$	$p \leq 0.05$	80.72 ± 4.55	40.41 ± 3.09
Cadmium	$p \leq 0.001$	$p \leq 0.01$	NS	0.04 ± 0.01	0.02 ± 0.01
Cobalt	$p \leq 0.001$	$p \leq 0.001$	$p \leq 0.001$	0.26 ± 0.02	0.16 ± 0.02
Copper	$p \leq 0.001$	$p \leq 0.05$	$p \leq 0.01$	17.14 ± 1.62	13.47 ± 1.23
Iron	$p \leq 0.001$	$p \leq 0.001$	NS	114.82 ± 11.38	75.86 ± 9.80
Manganese	$p \leq 0.001$	$p \leq 0.001$	$p \leq 0.001$	70.79 ± 80.5	186.21 ± 69.78
Molybdenum	$p \leq 0.001$	$p \leq 0.001$	$p \leq 0.001$	1.56 ± 0.11	0.28 ± 0.09
Lead	NS	NS	NS	0.54 ± 0.02	0.54 ± 0.03
Zinc	NS	NS	NS	33.74 ± 1.91	37.57 ± 2.65

a Group means have been pooled across two habitats (riparian and non-riparian) and six survey sites.
b SE = standard error.
c NS = not significant.

Ordination indicated that axes I–III (with 25%, 22% and 16% explanatory power, respectively) are needed to explain differences in leaf chemistry of the investigated species (Figure 23.2). However, the major difference between cat's claw creeper and other vines lies in the combination of axes II and III. Phosphorus and molybdenum (on axis II) and nitrogen, potassium, aluminium, copper, iron and cobalt ions (on axis III) were the major driver variables. Interestingly, leaf chemistry of the native *P. straminea* is the closest to cat's claw creeper of all non-invasive species tested, confirming the often-observed overabundance of this native vine in remnant vegetation and the notion that the species has to be managed in its own right.

Funding in 2010–11

Queensland Government

Collaborators

- Dr Tanya Scharaschkin (Queensland University of Technology, Science and Engineering Faculty)
- Dr Alan Andersen (CSIRO Ecosystem Sciences, Darwin)

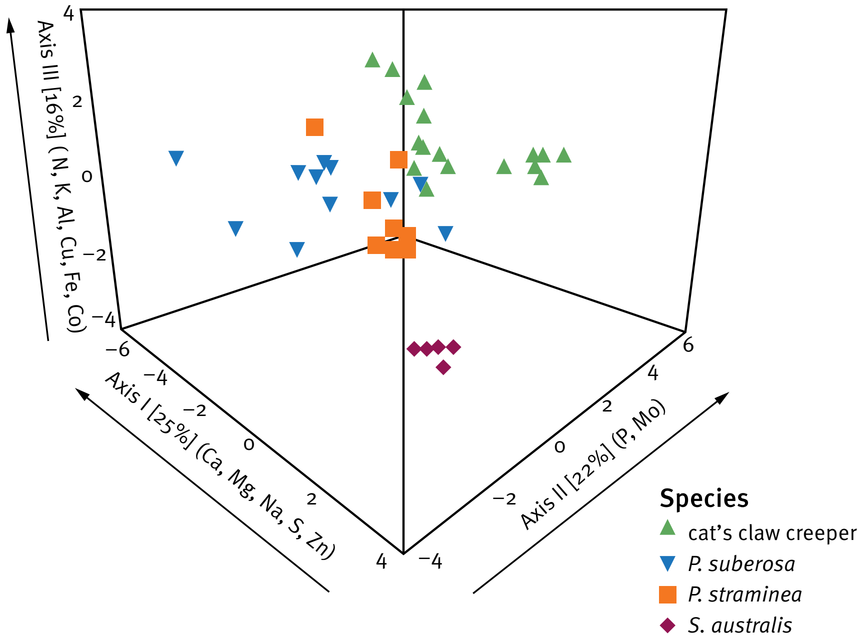

Figure 23.2 Ordination on three principal axes of leaf chemistry in cat's claw creeper and co-occurring introduced non-invasive (*P. suberosa*) and native (*P. straminea* and *S. australis*) species: each data point represents a single plant; arrows indicate direction and magnitude of leaf traits driving each axis; percentages refer to data variation captured by each axis

More information

Key publications

Osunkoya, OO, Polo, C & Andersen, AN 2011, 'Invasion impacts on biodiversity: responses of ant communities to infestation by cat's claw creeper, *Macfadyena unguis-cati* (Bignoniaceae) in subtropical Australia', *Biological Invasions* 13(10): 2289–302.

Osunkoya, OO & Perrett, C 2011, '*Lantana camara* L. (Verbenaceae) invasion effects on soil physicochemical properties', *Biology and Fertility of Soils* 47(3): 349–55.

Osunkoya, OO, Pyle, K, Scharaschkin, T & 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): 132–8.

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

24. Cabomba (*Cabomba caroliniana*) ecology

Project dates

October 2010 – July 2012

Project leader

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Other staff in 2010–11

Cameron Clark

Objectives

- Research the ecological habitat requirements and competitiveness of cabomba.
- Investigate the regeneration ability and establishment of cabomba fragments to predict dispersal.

Rationale

Cabomba (*Cabomba caroliniana*) is a submerged aquatic weed originating from South America. It is a popular aquarium species and was introduced to the wild worldwide through intentional propagation for the aquatic plant trade and disposal of surplus aquarium material. Today, it is a serious aquatic weed in many countries, including Australia, the United States and China. Cabomba was first recorded in Australia in 1967 and is today naturalised in several states. It is a WONS and a Class 2 declared weed in Queensland. Even though cultivation and sale of cabomba is now prohibited, the plant is increasing its range and could potentially establish in large parts of Australia with suitable habitat. Cabomba predominantly reproduces through vegetative propagules (stem fragments); viable seeds have so far been observed only in Northern Territory populations. Cabomba readily spreads within catchments through the movement of fragments via water currents, particularly in floodwaters. However, humans are the main vector for dispersal between waterbodies, mainly through boating and fishing activities (fouling of fragments in equipment).

Once established, cabomba has serious environmental and economic impacts and is difficult to control due to limited availability of effective control options. While there is general knowledge in aquarium literature about culturing conditions for cabomba, there is little scientific data available about the ecology of cabomba, both from its native and introduced range.

Such knowledge is necessary to predict in which habitats cabomba is likely to establish. This will allow concentrated monitoring in areas deemed high risk, and therefore will improve the likelihood of detecting cabomba infestations in early stages, when successful removal is viable. A better understanding of cabomba ecology is also crucial for mitigating ecological and economic impacts of this serious pest.

Methods

Cabomba regeneration—nutrients in solution

Cabomba fragments (each consisting of a stem piece with a single node and one leaf pair) are incubated in shallow plastic containers filled with culture solution. There are five treatments (five replicates each): no nutrients, trace elements only, low nutrients (0.5 mg nitrogen L^{-1}), medium nutrients (1 mg nitrogen L^{-1}) and high nutrients (5 mg nitrogen L^{-1}).

These nutrient concentrations are representative of trophic statuses of freshwater systems: ultra-oligotrophic (trace elements only), oligotrophic (low nutrients), mesotrophic (medium nutrients) and eutrophic (high nutrients). We inspect fragments weekly and assess the number of regenerating fragments (new shoot development from nodes).

Cabomba establishment—substrate types

We establish 16 outdoor mesocosms (each 800 L) with a 10 cm substrate layer comprising a lower 5 cm layer of substrate mixed with topsoil and an upper 5 cm layer of clean substrate to prevent nutrient leaching. There are four substrate treatments (four replicates each): sand (< 0.5 mm), fine gravel (< 5 mm), coarse gravel (< 20 mm) and cobbles (> 100 mm). The tanks are filled with rainwater and seeded with 75 g wet mass of cabomba material consisting of approximately 100 stem fragments (a mix of single-node fragments and longer stem pieces). After 8 months we drain the mesocosms and measure the total cabomba wet mass and stem density. Water quality is monitored throughout the experiment.

Cabomba regeneration—substrate quality and pH

Four 100 L aquariums are filled with a mixture of tap water and distilled water in the laboratory and trace elements and micronutrients are added. In three tanks, we adjust the pH through CO_2 injection to pH 6.5, 7.0 and 8.0; the fourth tank does not receive added CO_2 and varies in pH from 7.5 to 8.0. In each tank we plant 10 cm long apical cabomba shoots in little pots filled with four different mixtures of sand and topsoil: sand only, 25% topsoil, 50% topsoil and 100% topsoil. There are three pots of each substrate quality per tank. Shoot growth and establishment of new shoots is then monitored over 6 weeks, after which we harvest all cabomba and measure the dry mass of shoots and roots.

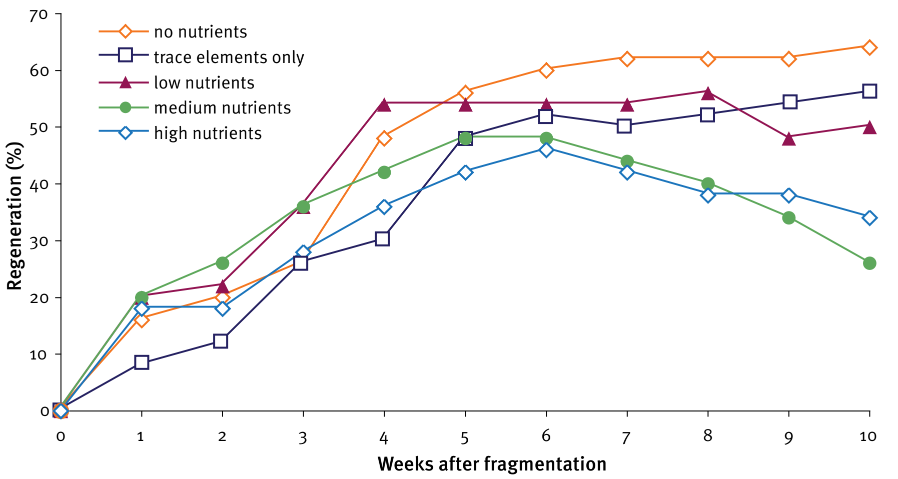

Figure 24.1 Regeneration of cabomba fragments (see Photo 24.2) as affected by nutrient availability

Progress in 2010–11

Cabomba regeneration—nutrients in solution

Cabomba regenerated readily from single-node fragments, independent of nutrient availability in the culture solution (Figure 24.1 and Photo 24.1). Only 4 weeks after fragmentation, about 50% of all fragments grew new shoots. Towards the end of the experiment, there was a decrease in cabomba health in the high and medium nutrient concentrations due to excessive algal growth. Overall this means that cabomba does not depend on nutrients available in the water to regenerate, but is probably able to use internally stored nutrients for initial growth. Consequently, cabomba would be able to establish from single-node fragments even in habitats with low nutrient availability (oligotrophic systems).

Cabomba establishment—substrate types

The experiment was conducted from March to December 2010. There was a pronounced difference between cabomba establishment in the mesocosms with different substrate types. Cabomba clearly prefers fine substrates (sand) and did not establish well even in fairly fine gravel (Figure 24.2). However, there was a fairly high variability in cabomba establishment, even within the same substrate treatment, indicating that other factors are also important. Nevertheless, while two of the sand mesocosms were completely filled with cabomba after 8 months (Photo 24.2), there was very little establishment of shoots in other substrate types. This clearly shows that cabomba establishment is limited to suitable substrates.

Photo 24.1 Cabomba fragments

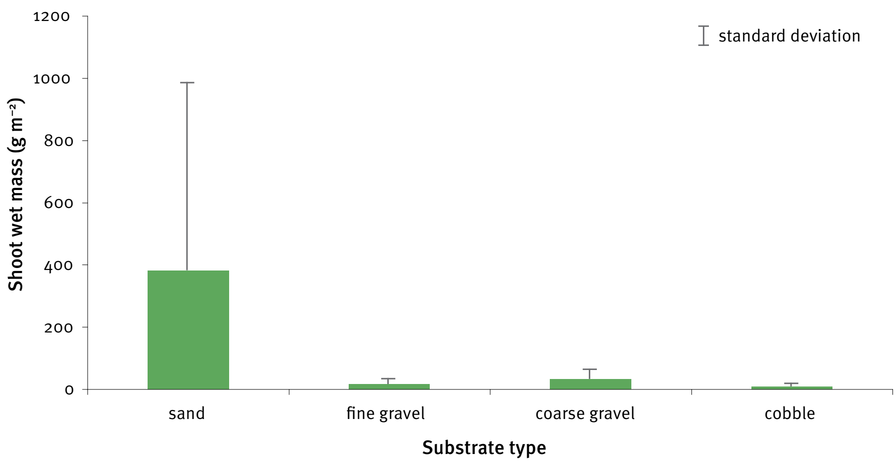

Figure 24.2 Cabomba establishment and growth, measured as shoot wet mass, as affected by substrate type

Photo 24.2 A fine sand mesocosm with strong cabomba growth after 8 months

Cabomba regeneration—substrate quality and pH

Cabomba fragments grew best in substrates with a low organic content, but also did well in substrates with a large proportion of topsoil (Figure 24.3). The sand-only treatment, which lacked organic content, was the only substrate that did not support good cabomba growth. However, growth in substrates was also influenced by the pH (Figure 24.3 and Photo 24.3). The best growth was achieved at pH 6.5 in the substrate with 25% topsoil. This shows that cabomba prefers slightly acidic conditions and the pH of the water is an overriding factor in overall growth performance. This experiment also indicates that cabomba depends upon organic content in the substrate for healthy growth. One possible reason for this could be that cabomba might not be able to take up all its nutrient requirements from water alone, but also depends on nutrient supply through the substrate.

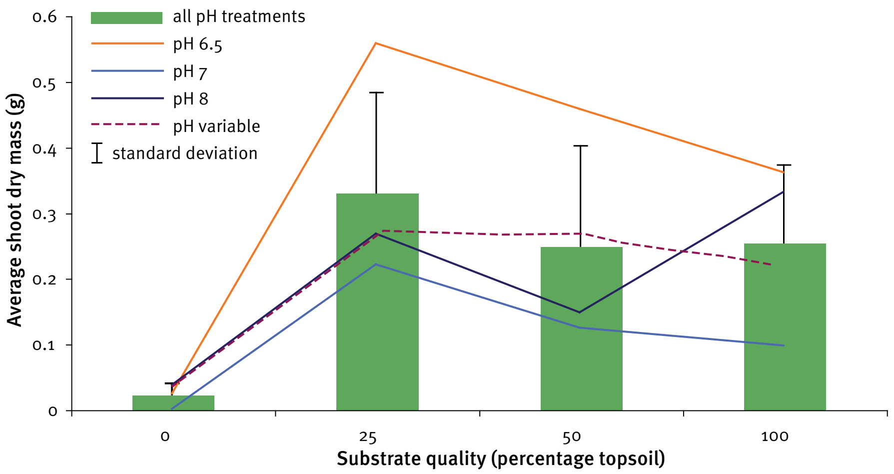

Figure 24.3 Cabomba establishment and growth, measured as shoot dry mass, as affected by substrate quality and pH of the water

Photo 24.3 Cabomba shoots growing in an experimental aquarium to investigate the influence of substrate quality on growth

Conclusions

Cabomba is able to regenerate successfully even from single-node fragments. After only 4 weeks, up to 50% of all propagules produced new shoots. Regeneration does not appear to depend on nutrient concentrations in the water. The pH of the water seems to be an overall limiting factor, with the plant preferring water that is slightly acidic. Cabomba appears to be able to establish even in nutrient-poor waters as long as nutrients are available in the substrate.

Funding in 2010–11

Land Protection Fund ($120 000)

Collaborators

- Brisbane City Council
- CSIRO
- Seqwater
- National Aquatic Weed Management Group
- Noosa and District Landcare
- Department of Primary Industries, Victoria

More information

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

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

Project dates

May 2009 – December 2011

Project leader

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Objectives

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

Rationale

Wild dogs (*Canis lupus familiaris* and *C. l. dingo*) include dingoes as well as hybrids of dingoes and domestic dogs. It is believed that they deliver biodiversity benefits by suppressing mesopredators (foxes and feral cats) and preying on overabundant large macropod species. However, they are also a threat to sheep and goat production—past satellite tracking of wild dogs shows that 25% of males disperse more than 100 km and up to 500 km from their natal areas. The frequency and magnitude of these movements make it unrealistic to establish buffers to protect sheep and goat producers from livestock predation.

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

Given such apparent benefits, guardian animals could prove to be a future management imperative for protecting sheep and goats from the ingress of dispersing wild dogs. Although guardian dogs are increasingly used by graziers, there is currently very little known about how guardian dogs 'work' in Australia—particularly in extensive grazing systems—and even less about their night-time movements and interaction with wild dogs. Anecdotal accounts suggest some guardian dogs are effective at preventing wild dogs from attacking livestock, while others have been seen associating with wild dog packs.

A critical management concern is the potential for guardian dogs to interbreed with wild dogs, producing larger, more aggressive and destructive hybrids. In this study, we investigate interbreeding on two properties with different approaches to the management of guardian dogs. On Dunluce Station, all working dogs are desexed according to best practice guidelines. On the second study site—Stratford Station, a beef cattle property south of Jericho in central western Queensland—guardian dogs are not desexed, are not bonded to the cattle and return to the homestead each morning.

Methods

Spatial and temporal movements

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

We overlay GPS location data for wild dogs and maremmas on satellite imagery of the properties using geographical information systems to identify any overlap of movements and territory boundaries. If any overlap exists, we investigate the temporal relationships between guardian dogs and wild dogs.

Interbreeding

DNA is collected from tissue samples or blood at the time of collaring and from dogs shot or trapped locally. It is analysed for genetic evidence of interbreeding.

Biodiversity impacts

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

Progress in 2010–11

Spatial and temporal movements

We monitored half-hourly locations of eight maremmas and hourly locations of six wild dogs on Dunluce Station for six months. Collars were recovered and downloaded in October 2010. For five of the six wild dogs, 864 hourly locations were recorded within the sheep paddocks or adjacent paddocks where one or more guardian dogs patrolled (Figure 25.1).

While many wild dog forays into sheep paddocks occurred overnight (twice as many night-time locations as day-time locations), and came from refuge areas on the Flinders River 20 km away, some stayed in the open grazing paddocks for up to two days (Figure 25.2).

During these intrusions, guardian dogs appeared to remain more or less stationary, closely associated with the sheep, and showed no obvious pursuit of wild dogs. At times wild dogs circled the maremma locations or camped during the middle of the day in paddocks containing sheep, yet remarkably no sheep were attacked (Figure 25.3).

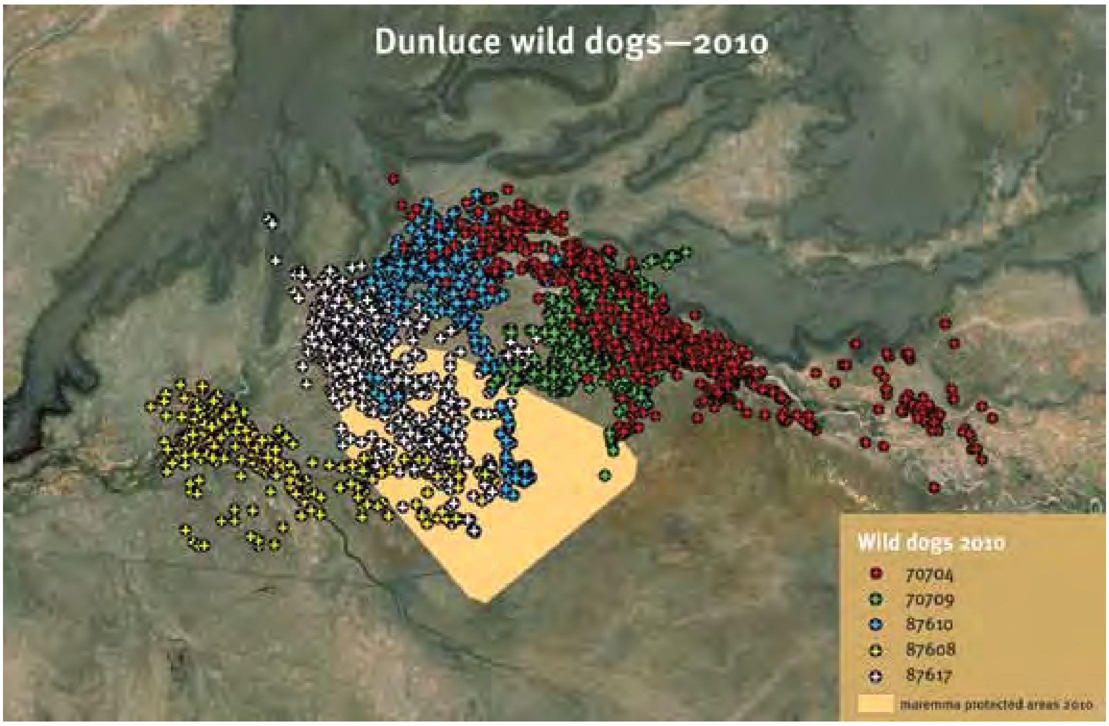

Figure 25.1 Wild dog GPS locations—up to 20% were in sheep paddocks or adjacent paddocks patrolled by maremmas

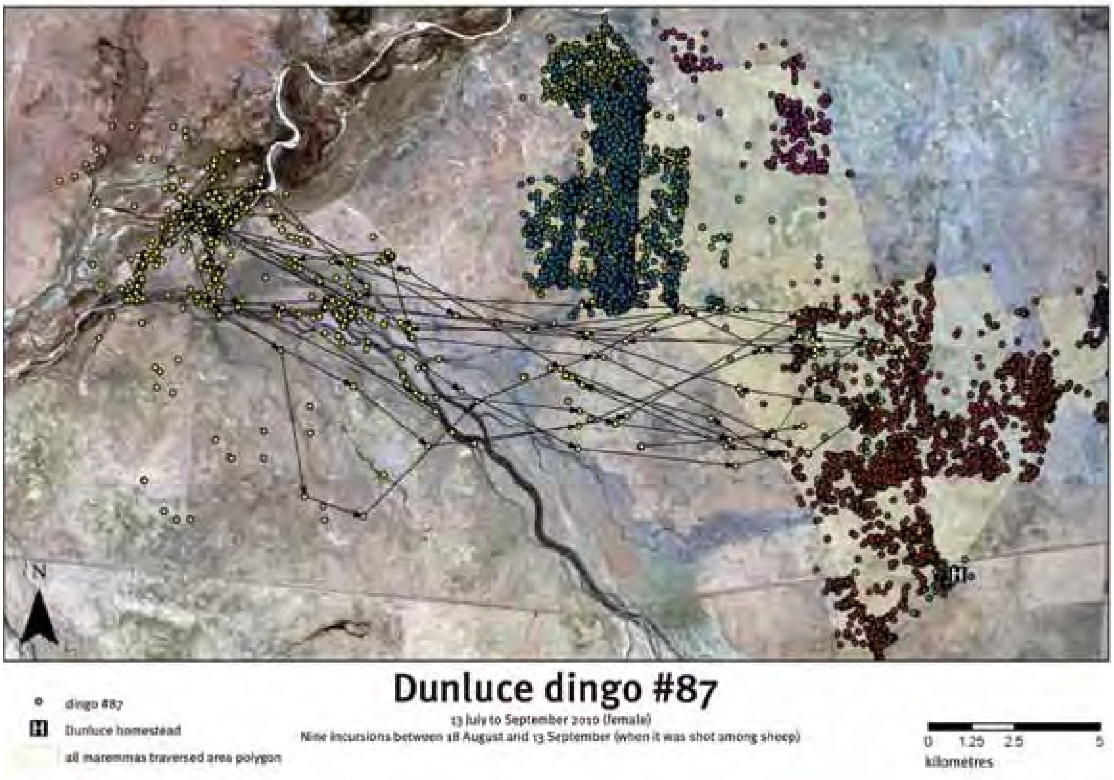

Figure 25.2 Wild dog forays of more than 20 km from refuge areas on the Flinders River to sheep paddocks

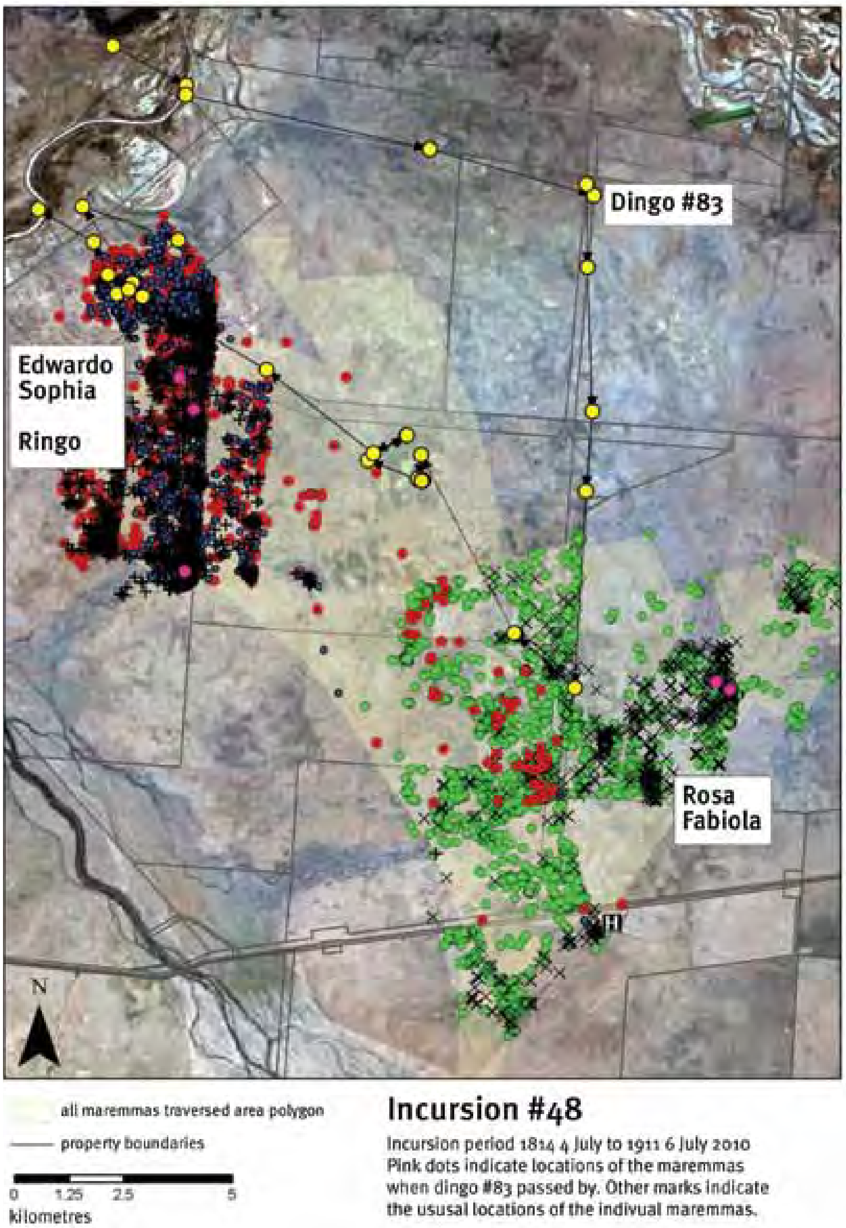

Figure 25.3 Locations of five maremmas (highlighted in pink) when a wild dog foraged in their sheep paddock

Interbreeding

DNA analysis of blood samples taken from wild dogs showed no evidence of interbreeding between maremmas and wild dogs on Dunluce Station. However, all working maremmas on Dunluce Station are desexed or treated to prevent interbreeding.

Biodiversity impacts

The activity of rodents and birds (likely prey for feral cats and foxes) was similar for both sheep and cattle paddocks and was independent of the activity of foxes, maremmas and wild dogs. Fox and wild dog activity fluctuated between surveys, but these animals were mostly detected in the sheep–maremma paddocks rather than the cattle paddocks. No wild dogs were detected during the July survey (at whelping), yet tracking showed they were still making incursions into the area at this time.

In April 2011, we captured and collared eight wild dogs and six maremmas on Stratford Station. We will conduct wildlife surveys and DNA analysis of wild dogs similar to those on Dunluce Station.

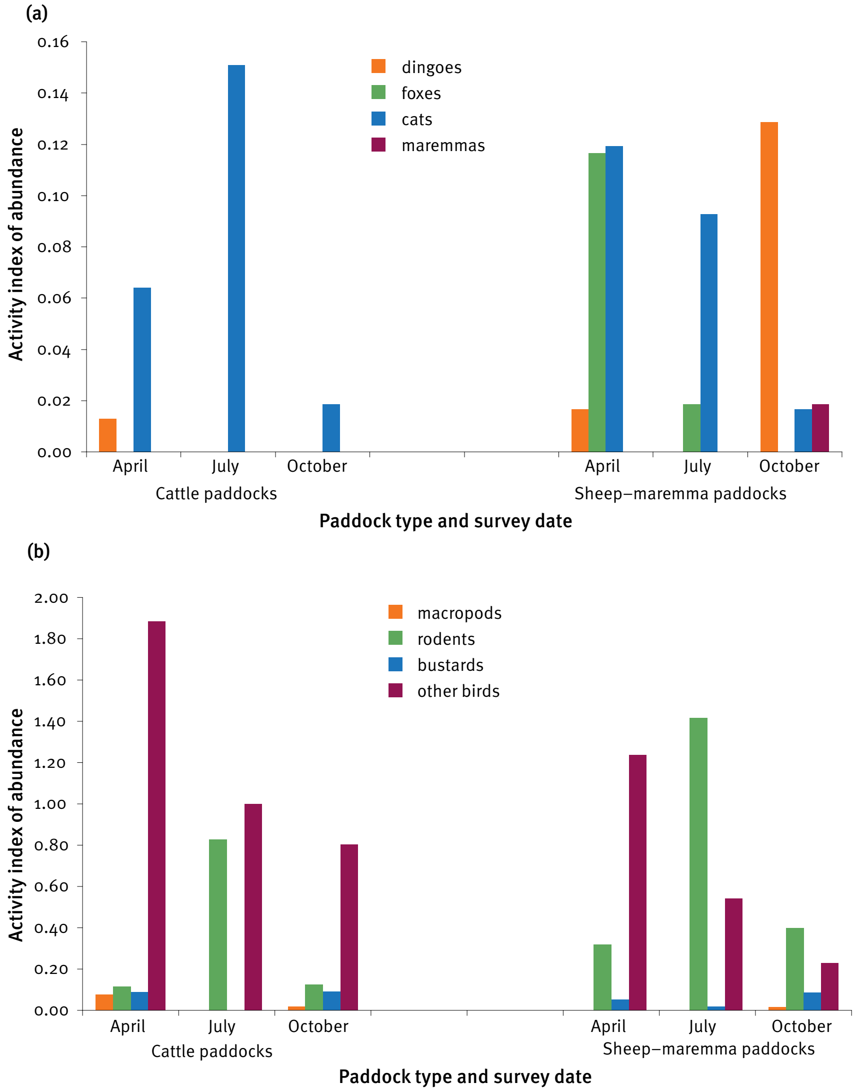

Figure 25.4 The activity of (a) predators and (b) wildlife at Dunluce Station in the sheep–maremma paddocks compared to the cattle-only paddocks as detected during surveys in April, July and October 2010

Funding in 2010–11

- Australian Pest Animal Research Program, Australian Government Department of Agriculture, Fisheries and Forestry (DAFF) ($30 000)
- Queensland Government

Collaborators

- Ninian Stewart-Moore (Dunluce owner, Leading Sheep North and Central West regional committee member)
- Robyn and Terry Brennan (Stratford Station owners, Desert Channels Queensland)

More information

Key publication

Allen, L & Byrne, D 2011, 'How do guardian dogs "work"?', in G Saunders & C Lane (eds), *Proceedings of the 15th Australasian Vertebrate Pest Conference*, Invasive Animals Cooperative Research Centre, Sydney, p.158.

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

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

Project dates

January 2007 – December 2010 (completed)

Project leader

Dr Matt Gentle
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Other staff in 2010–11

James Speed and David Aster

Objectives

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

Rationale

Pest managers often encourage commercial and recreational harvesting of feral pigs (*Sus scrofa*) because this is considered 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 (QMDC) 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 guides decision-making by pest managers.

Methods

We survey landholders throughout the QMDC area (the Border Rivers Maranoa–Balonne Natural Resource Management Region) using a combination of telephone and postal surveys. In addition to identifying hot spots of damage and areas with little control, the survey facilitates the selection of study sites for more intensive assessments of damage and density. Importantly, these surveys also raise awareness of the project throughout the rural community.

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

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

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

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

Findings

Pig damage is common throughout the QMDC area, with 63% of survey respondents reporting losses. Commodities reported as damaged include cereals, vegetables, legume crops, and lambs (by predation). Cereal crops in particular suffered considerable damage; these included sorghum (8.3%), wheat (3.3%) and barley (13.4%). Lamb predation was also high (16.1%). However, damage figures calculated from field assessments (sorghum 1.3% and wheat < 0.4%) appear low relative to both landholder perceptions and previous studies. Caley (1993) reported 40% damage to sorghum crops and Pavlov (1980) found 4–7% damage in wheat crops. These results may reflect seasonal conditions at study sites or pig densities at the time of assessments. Nevertheless, assuming that the conservative field estimates are representative of feral pig damage throughout the QMDC area, the mean annual loss per sorghum producer is $843 and per wheat producer is $448. Awareness of this impact will help to justify and promote feral pig control measures.

Results from aerial surveys on the study sites (conducted from November 2007 to April 2010) and the macropod monitoring program (conducted annually from 1991 to 2010) demonstrate that feral pig populations are both widespread and persistent throughout Queensland, reaching high densities when conditions are favourable. Populations in the QMDC area can reach high densities—4.4 pigs km^{-2} were recorded at Southwood in March 2008 (Figure 26.1) and historical records show densities of 6.3 pigs km^{-2} at Westmar in 1999. Predominant land management practices in the region offer fragmented landscapes with vast cropping and grazing areas, natural watercourses and stock waters, which provide pigs access to water, shelter and sufficient food to maintain relatively high densities.

Feral pigs have long been established throughout the region and should have reached a long-term equilibrium abundance. This equilibrium is dynamic and is best considered as an average density around which the population fluctuates, but with no long-term trend. The survey data provides additional empirical evidence that the density of feral pigs is not constant but fluctuates from year to year, most likely as determined by environmental influences.

In an effort to reduce abundance and associated damage, landholders commonly control feral pig populations through poisoning, trapping and harvesting. However, to maintain reduced densities of feral pigs, higher rates of population growth following control must be stopped. On all QMDC study sites, regardless of harvesting and control activities, the rate of population growth was not significantly different from zero, indicating that populations were stable—although fluctuating—during the course of the study. There was no clear decline in abundance. Control activities had, at best, been able to suppress growth.

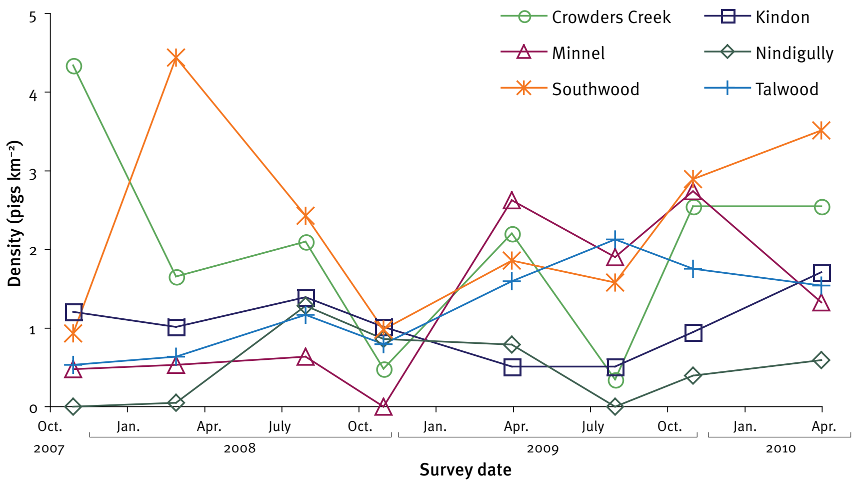

Figure 26.1 Feral pig density on the six study sites, calculated from aerial surveys

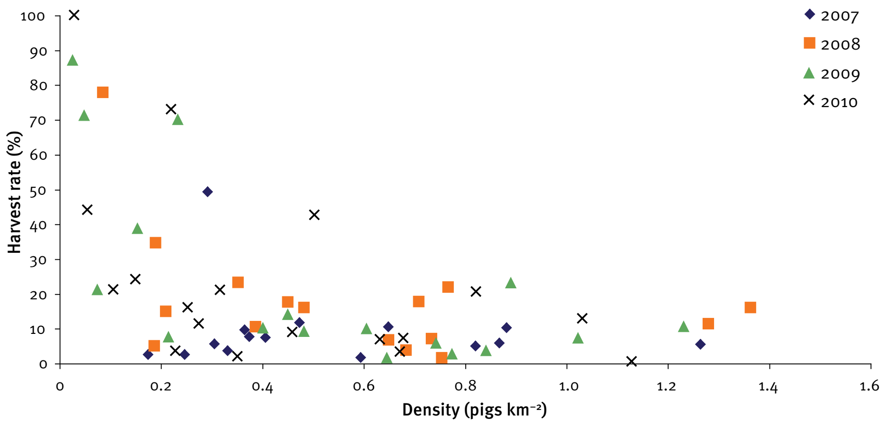

Figure 26.2 Commercial harvesting rate and feral pig density for Queensland macropod survey blocks, 2007–2010 (excluding blocks where no feral pigs were observed during surveys)

The ineffectiveness of commercial harvesting is not surprising, considering the low harvest rates relative to the maximum rate of population growth (r_{max}) that can be achieved under ideal environmental conditions. For a feral pig population growing at r_{max}, between 60 and 70% of the population needs to be removed each year to keep it stable. Harvest rates only occasionally exceeded r_{max} and such occurrences were not maintained across sites and years (Figure 26.2). Moreover, harvest rates were elevated only at low densities. This indicates that while harvest rates may be sufficiently high to hold populations at low densities, the population is likely to recover following an increase in food supply or a reduction in harvest effort.

References

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

Pavlov, PM 1980, *The diet and general ecology of the feral pig (*Sus scrofa*) at Girilambone, NSW*, MSc Thesis, Monash University, Melbourne.

Funding in 2010–11

- QMDC ($51 000)
- Queensland Government

Collaborators

- QMDC
- Safe Food Queensland
- Australian Quarantine and Inspection Service
- Game and meat processors

More information

Key publication

Gentle, M, Pople, T, Speed, J & Aster, D 2011, *Assessing the role of harvesting in feral pig (*Sus scrofa*) management*, Final report to the Queensland Murray–Darling Committee, Toowoomba.

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

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

Project dates

February 2009 – December 2010 (completed)

Project leader

Dr Matt Gentle
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Other staff in 2010–11

James Speed

Objectives

Assess the use of satellite imagery and geographical information systems to measure feral pig damage to grain crops. Key objectives are:

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

Rationale

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

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

Methods

Wheat crops in the Moonie–Goondiwindi area of southern Queensland are field surveyed for feral pig damage. Targeted crop types and paddock locations include those known to have historically suffered high levels of damage. We record the location of trampled patches (using a GPS), area damaged and intensity of damage within this area (e.g. 80% loss), along with species responsible for the damage.

We use the data to establish characteristics of feral pig damage in crops, including the location and typical areal extent of pig damage. Using this information, we specify a minimum mapping unit and image pixel size suitable for mapping pig damage. This allows us to select suitable image data, including government archive SPOT (satellite pour l'observation de la terre), Ikonos, Quickbird and Geoeye.

Then we analyse imagery (recorded at the same time as field data) to determine unique characteristics of feral pig damage that could be used to develop a suitable mapping approach. Once a suitable approach is developed, we apply it to other current and archival imagery to identify areas of pig damage.

Findings

We were able to identify many patches of feral pig damage in field assessments and successfully captured suitable Quickbird imagery. However, we were unsuccessful in using satellite imagery to identify feral pig damage in wheat crops. Despite several attempts using visual or pixel-based approaches, there was no apparent match between field survey points and evident damage in the images.

Firstly, patches of feral pig damage recorded during field assessments were typically small, often only marginally larger than a single pixel in the image. However, even the numerous large patches of feral pig damage recorded (e.g. an area of close to 70 m × 70 m at Southwood) could not be successfully distinguished in the imagery.

Secondly, regardless of the size of the damaged area, the characteristics of pig damage were difficult to distinguish from underlying damage associated with dryland cropping systems, including damage from poor crop establishment, wind and scalding. For example, gilgais (soil depressions) are common in the study area and typically fill with water during wet periods. These and other variations in soil conditions are responsible for significant natural variation in crop establishment and yield, which could easily be mistaken for feral pig damage on imagery. Additionally, wheat crops have a relatively open canopy, particularly as the crop matures and approaches ripening (grain-fill), which further complicates differentiation from damaged areas.

Thirdly, determining the cause of crop damage during field assessments is not straightforward. Some interpretation by the observer is usually required through inspecting field signs either on the ground or on damaged plants. Some ground-truthing of crop damage identified on satellite imagery would always be required to establish the species responsible.

Furthermore, the capture process associated with Quickbird images can prove problematic. Factors impeding successful image capture include the size and shape of the capture area (areas > 18 km wide need to be captured in at least two passes), significant cloud cover at the time of pass and the priority of other pending image capture requests.

Those results, when combined with the cost, analytical difficulties, practicalities and logistical issues with data collection, indicate that using satellite imagery for assessing feral pig damage to grain crops currently has serious deficiencies. Further studies should only be considered if new advances in image capture (e.g. inclusion of middle-infrared bands) or analysis have been made.

Reference

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

Funding in 2010–11

- Australian Pest Animal Research Program, DAFF ($22 000)
- Queensland Government

Collaborator

Prof. Stuart Phinn (Centre for Spatial Environmental Research, The University of Queensland)

More information

Key publication

Gentle, M, Phinn, S & Speed, J 2011, *Assessing pig damage in agricultural crops with remote sensing*, Final report to the Australian Government Department of Agriculture, Fisheries and Forestry, Canberra.

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

28. Non-target impacts of 1080 meat baits for feral pigs (*Sus scrofa*)

Project dates

June 2010 – June 2012

Project leader

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Other staff in 2010–11

James Speed, Tony Pople and Michael Brennan

Objective

Quantify the population-level impact on non-target species, specifically birds, from 1080 meat baiting practices used for feral pig control.

Rationale

Bait containing 1080 (sodium fluoroacetate) is widely used for the routine control of feral pigs in Queensland. Meat baits are popular in western and northern pastoral areas since they can be distributed aerially. Although much research has assessed the effectiveness of baiting practices, little is known about the long-term impact of such practices on other species.

The APVMA conducted a review into the use of 1080 meat baits for feral pig control. This review indicated that the practice may be harmful to a range of non-target animals, largely because of species' sensitivity to 1080 (i.e. the toxicity of 1080). These concerns are supported by field observations from south-western and northern Queensland indicating some bait uptake by non-target species. Species observed include corvid and raptor species such as the Australian raven (*Corvus coronoides*), Australian magpie (*Gymnorhina tibicen*), whistling kite (*Haliastur sphenurus*), black kite (*Milvus migrans*) and wedge-tailed eagle (*Aquila audax*), and varanid species such as Gould's goanna (*Varanus gouldii*) and the lace monitor (*Varanus varius)*.

Published susceptibility data indicates that many of these species are (theoretically) at risk through primary poisoning from 1080 meat baits. For example, for an average adult Australian raven (of body weight 585 g), about 3 mg of 1080 (less than 5% of the 1080 content in one bait) would be a lethal dose. However, it is not certain that this **theoretical** risk translates into a **real** impact. Occasionally, bird carcasses (primarily raptors) have been found following baiting operations and, in some cases, laboratory analyses have confirmed 1080 poisoning as the cause of death. Yet we are unsure whether these cases represent a level of mortality that could threaten species' population viability or disrupt some ecological function performed by these species. No trial to date has demonstrated any **population** impact on non-target species. By examining such impacts, this project helps ensure that baiting operations are acceptably target-specific, and that 1080 use is responsible and ecologically sustainable.

Methods

Population counts

To detect any changes in the abundance of non-target species following standard aerial baiting operations, we count birds (targeting raptor and corvid species) before and after baiting on treatment sites and on control sites not exposed to baiting. These counts occur along driven transects for up to 10 days in each period. All data is recorded using distance-sampling techniques to provide density estimates and is analysed using the computer program Distance 6.0.

Monitoring of individual birds

We also monitor individual birds of a susceptible non-target species during a 1080 baiting campaign to determine levels of mortality due to baiting. Up to 15 individual Australian ravens are trapped and fitted with radio transmitters via elasticised harnesses on each treatment site and a control site. We then monitor their mortality for 2–6 weeks post-baiting, depending on the level of harness/transmitter failure.

Monitoring of bait uptake and carcass searches

During baiting, we further monitor a sample of bait stations (up to 40) daily via remote photography or soil plots to determine the proportion of baits removed and the identity of species removing baits. All monitored baits have radio transmitters incorporated to report the fate of removed baits, for example moved (transmitter found within bait) or consumed (transmitter found without bait).

We also search and collect carcasses of non-target species for toxicological analyses to confirm the cause of death.

This research is conducted under an animal ethics permit, CA 2009-06-360.

Progress in 2010–11

We completed a preliminary population count trial at Culgoa Floodplain National Park and three nearby properties (Kulki, North Kulki and Tambingey) south of Bollon, south-western Queensland, in May–June 2011. Culgoa Floodplain National Park was aerially baited for feral pigs as part of routine management and served as the treatment site; Kulki, North Kulk and Tambingey served as control sites.

Density estimates were calculated for species where a sufficient number of sightings were recorded in the pre-baiting period. Initially, separate detection functions were calculated for each site/species combination, but some were subsequently pooled (to obtain a global detection function) where they were not significantly different.

Photo 28.1 An Australian raven inspecting a goat carcass at an unset bait station near Culgoa Floodplain National Park, south-western Queensland

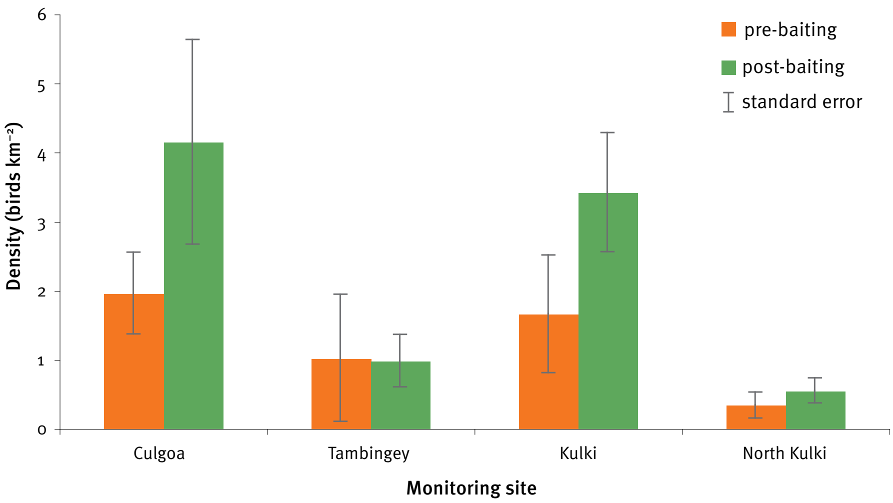

Figure 28.1 Pre-baiting and post-baiting densities of Australian raven at four monitoring sites in south-western Queensland

Densities of the Australian magpie, pied butcherbird and wedge-tailed eagle were not significantly different pre-baiting and post-baiting at Culgoa Floodplain National Park or the control sites. The abundance of Australian ravens, however, significantly increased—effectively doubled—following baiting at Culgoa Floodplain National Park (Figure 28.1). Raven densities also appeared to increase at Kulki and North Kulki post-baiting, but these differences were not statistically significant. Densities on Tambingey were stable during the same period.

While results to date suggest minimal, if any, impact on susceptible bird species, further monitoring is required to investigate effects on long-term abundance. Further replication during the October–November 2011 baiting period will also help account for any confounding effects from bird movements (emigration or immigration) and bait distribution (e.g. increased food availability).

Funding in 2010–11

Queensland Government

Collaborators

- DERM
- The University of Queensland

More information

Key publication

Gentle, M 2010, 'What gets killed by meat baits for feral pigs?', in *Proceedings of the 3rd Queensland Pest Animal Symposium*, Gladstone, Queensland.

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

29. Feral pig (*Sus scrofa*) best practice research in northern Queensland

Project dates

July 2009 – June 2012

Project leader

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Other staff in 2010–11

Brian Ross

Objective

Improve feral pig management in the dry tropics of northern Queensland.

Rationale

Large numbers of feral pigs continue to cause environmental and economic impacts in the dry tropics of northern Queensland. While there are several control techniques available for feral pigs, refinement of these is important to improve efficacy and minimise non-target impacts. For broadscale control, ground and aerial baiting are two of the most practical and efficient options, but these need to be timely and strategic. Research over several years has focused on establishing appropriate baiting densities and practices (e.g. strategic versus blanket baiting). The next step is to determine whether concentrated repeat baiting can offer better control than a one-off baiting program.

Methods

Along the frontage of the Burdekin and Star rivers (north of Charters Towers), we establish nine experimental areas (10 × 1 km) in blocks of three. Within each block we randomly assign experimental areas to one of three treatments: nil treatment (no baiting), standard baiting (once only) or pulse baiting (baiting at monthly intervals for three consecutive months).

We distribute the standard 1080 pig-strength formulation (72 mg in each 500 g meat bait) from an aircraft at a density of 12 baits km^{-2}. Following baiting, we monitor population knockdown through activity transects and camera-capture sampling.

Progress in 2010–11

In September 2010, we undertook initial aerial baiting for both the standard (one-off) and pulse baiting treatments. This was followed by further baiting in the pulse baiting treatment areas in October and November 2010. Monitoring revealed no significant differences in the feral pig populations before and after treatments. This was most likely associated with prolonged rainfall during 2010, which created an abundance of waterholes and allowed pigs to remain widely dispersed. Normally during the dry season feral pigs tend to concentrate around remaining permanent waterbodies, which allows control activities to be targeted to these areas. Because baiting was concentrated in strips along the edges of the rivers, a number of feral pigs may not have come in contact with the baits. A repeat of this project will be considered if additional external funding becomes available.

Funding in 2010–11

- Land Protection Fund ($128 000)
- Queensland Government

More information

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

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

Project dates

2000–2012

Project leader

Dr David Berman
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Other staff in 2010–11

Michael Brennan

Objectives

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

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

Rationale

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

Rabbit incursions into the DDMRB area have occurred for many years and appear to be more frequent recently, although rabbits generally have not yet established permanent warren systems within this area. Genetic studies comparing rabbit populations inside and outside the DDMRB area can help identify the source of these rabbit incursions. Targeting these source areas could help prevent further incursions into the DDMRB area; it could also help minimise the cost and maximise the long-term effectiveness of rabbit control in south-eastern Queensland.

Methods

Benefits of rabbit control

In the study site at Cottonvale, south of Warwick, 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 impacts of rabbits and separate these from impacts caused by cattle. To monitor rabbit and wildlife activity, we distribute sand tracking plots and also install movement-sensing cameras. Once we have measured the differences between lightly infested and heavily infested areas, we destroy warrens by ripping. Then we measure the effectiveness of this method for rabbit control as well as the associated rate and extent of recovery of pasture and biodiversity.

Genetic studies

We also obtain ear-tissue samples from rabbits at 19 locations both inside and outside the DDMRB area. Susan Fuller from the Queensland University of Technology conducts genetic analyses on extracted rabbit DNA.

Progress in 2010–11

Benefits of rabbit control

Research to date suggests that native plants and animals benefit significantly from low rabbit densities achieved by the rabbit-proof fence and other control activities. The benefit to agricultural production is also significant but requires further quantification.

Genetic studies

Total DNA was extracted from ear-tissue samples obtained from 2007 to 2010 and nine loci were analysed. The analysis indicated five genetically distinct populations: Killarney, Hampton, Ipswich, Waterford West – Chambers Flat and Eukey–Cottonvale (Figure 30.1).

The pie charts in Figure 30.1 show the proportion of sampled rabbits in each of these populations. Larger coloured areas are threatened by dispersing rabbits (i.e. are within 20 km of warrens reported via RabbitScan). There is likely to be limited rabbit movement between green, pink and blue areas.

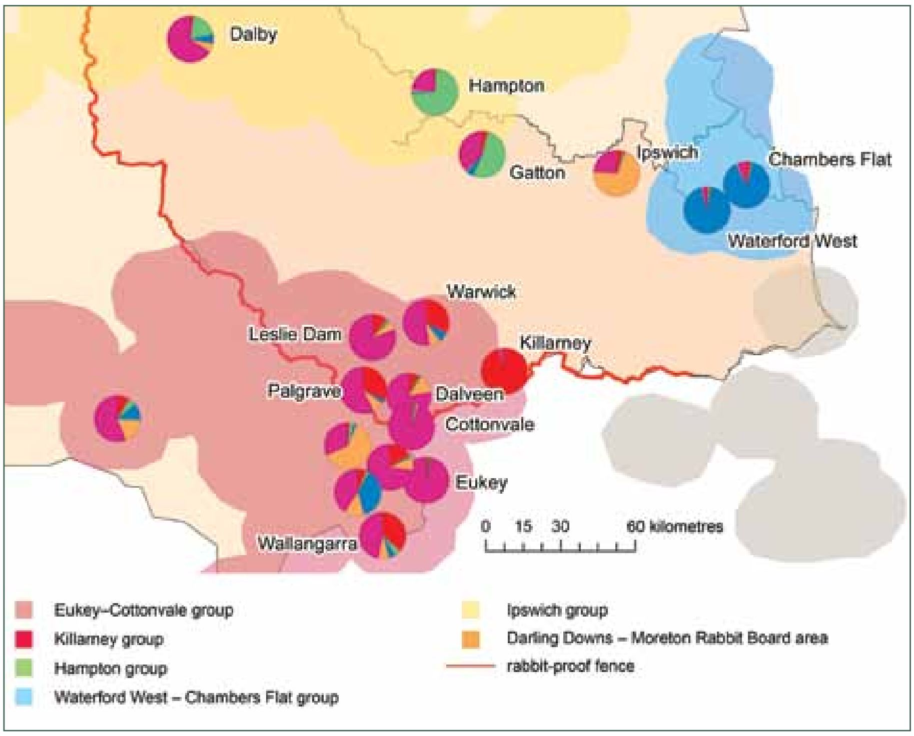

Figure 30.1 The genetic make-up of rabbit populations at 18 locations in south-eastern Queensland

Rabbits within each site are highly genetically related, but gene flow (dispersal) between sites appears to be restricted. Cottonvale and Eukey rabbits showed a high degree of genetic similarity. Dalveen and Leslie Dam populations were also quite similar to the Eukey–Cottonvale populations, indicating that some restricted gene flow has occurred among these sites in the past.

Rabbits from the clean and dirty side of the fence at Cottonvale were genetically very similar, suggesting a shared ancestry. Geographically, the closest site to Cottonvale was Dalveen, and this site was composed of individuals that shared 78% ancestry with the Eukey–Cottonvale populations. Therefore, rabbits that have recently invaded the clean side of the fence at Cottonvale and Dalveen are likely to have originated from the dirty side of the fence at Cottonvale, probably via occasional holes in the fence. Since, for rabbits, Eukey appears to be a more productive area than Cottonvale, it is likely that Eukey is the original source of rabbits. Eukey–Cottonvale is also the likely source of rabbit populations at Leslie Dam. Rabbits from Palgrave and Warwick display mixed ancestry. Rabbit populations in these areas are likely to have been founded by a combination of migrants from Eukey–Cottonvale and Wallangarra. The rabbit population at Killarney was most likely founded by rabbits from Warwick.

These results suggest that it is important not only to eradicate populations within the DDMRB area but also to control rabbits at Cottonvale, Eukey and Wallangarra to reduce the chance of further invasions. These areas are the sources of rabbits invading at least the southern part of the DDMRB area. Therefore, control of rabbits in these areas has the potential to reduce rabbit numbers over a much larger surrounding area. Warren ripping at Cottonvale and Eukey (coordinated and partly funded by the QMDC) has significantly reduced rabbit populations to the extent that they may no longer be sources of rabbits for surrounding areas. Further work is required to ensure there are no large warren systems remaining, while ripping is also required at Wallangarra.

Rabbits from Dalby, Gatton and Hampton displayed similar ancestry, but the sources of these populations are unknown. The sources of the Chambers Flat – Waterford West and Ipswich populations are also unknown. Additional tissue samples need to be collected from areas to the north of the DDMRB and the Tweed Heads area to identify possible sources of these rabbits.

Funding in 2010–11

Land Protection Fund ($20 000)

Collaborators

- Susan Fuller (Queensland University of Technology)
- Mark Ridge (DDMRB)
- Shane Cartwright (Queensland Murray–Darling Committee)
- Harley West (Granite Borders Landcare)

More information

Key publications

Berman, D, Brennan, M & Elsworth, P 2011, 'How can warren destruction by ripping control European wild rabbits (*Oryctolagus cuniculus*) on large properties in the Australian arid zone?', *Wildlife Research* 38(1): 77–88.

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

Scanlan, JC, Berman, DM & Grant, WE 2006, 'Population dynamics of the European rabbit (*Oryctolagus cuniculus*) in north-eastern Australia: simulated responses to control', *Ecological Modelling* 196(1–2): 221–36.

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

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

Project dates

July 2008 – August 2012

Project leader

Dr David Berman
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Other staff in 2010–11

Michael Brennan

Objectives

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

Rationale

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

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

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

To collect recent rabbit distribution and abundance data across 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. RabbitScan has now given rise to FeralScan (www.feralscan.org.au), through which other pest animals are also mapped.

Methods

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

We also attempt to identify key areas requiring priority treatment, which may be the sources of rabbits for surrounding areas. First, we overlay historical and RabbitScan data points (including a 20 km buffer representing the area immediately threatened by dispersing rabbits). The area of overlap most likely represents the area where rabbit populations have been most stable. We then examine the proportion of RabbitScan points with highest warren density within the area of overlap. These areas are likely to be the most productive breeding places for rabbits. We expect the highest warren densities to be located mainly in the area of overlap.

We further investigate whether the density scores reported by RabbitScan respondents are correlated with latitude, which is known to have a major influence on rabbit distribution and abundance. We expect the density of rabbits to be, on average, higher in the south than in the north.

Progress in 2010–11

From RabbitScan and other sources, we have obtained coordinates for a total of 9901 points where rabbits occur or have occurred in Australia. The area exposed to the impact of rabbits in Australia is at least 2 213 598 km^2 or 29% of the continent. The area within 20 km of RabbitScan points with the highest warren density is 84 021 km^2 or 4% of the total area exposed to the impact of rabbits (Figure 31.1). Interestingly, 82 of 111 points (74%) with the highest warren density were in the area of overlap between historical and RabbitScan points.

Rabbit density as reported by RabbitScan respondents decreased with latitude (Figure 31.2), matching expectations from conventional scientific knowledge. This suggests that respondents are reliably reporting density estimates and that RabbitScan can be useful for monitoring trends within selected areas (catchments or council areas) of Australia.

This work highlights the importance of mapping the distribution and abundance of rabbits for identifying areas that require increased control efforts. The full value of RabbitScan will be realised once a few years of data have been collected and we can monitor the effects of control activities.

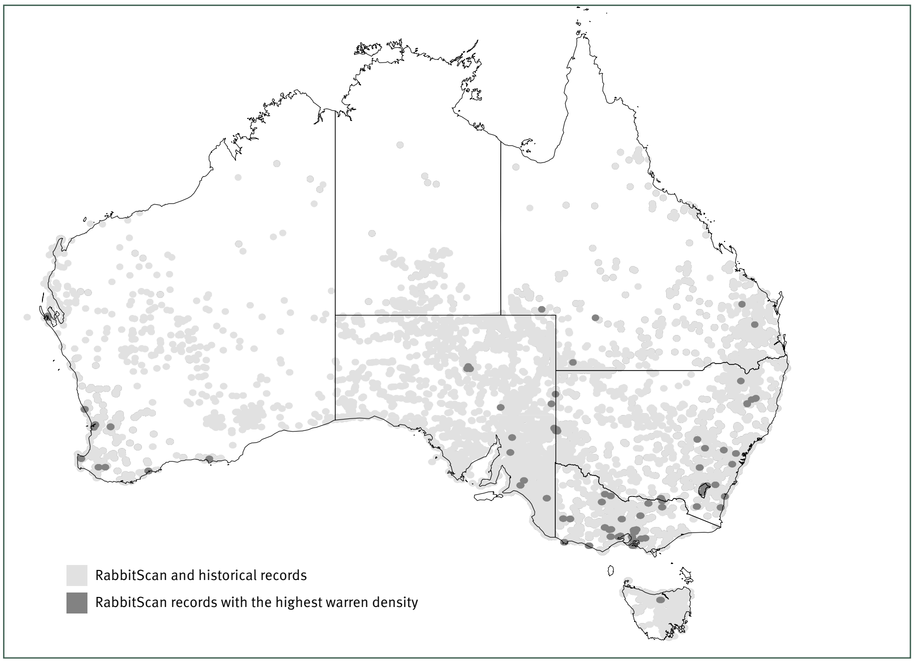

Figure 31.1 The total area exposed to the impact of rabbits in Australia (both historically and as reported via RabbitScan) and areas with the highest warren density as reported via RabbitScan; data points are surrounded by 20 km buffers representing the areas immediately threatened by dispersing rabbits

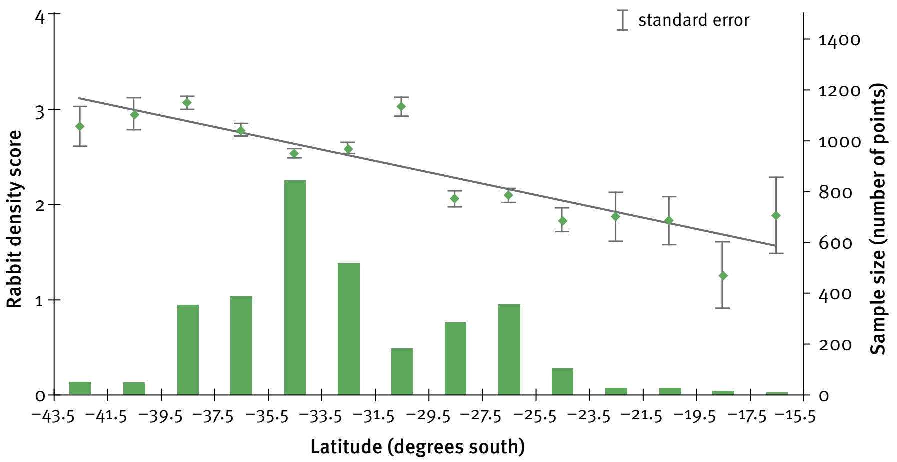

Figure 31.2 Rabbit density scores by latitude as reported by RabbitScan respondents and the sample sizes (shown as bars) for these latitudes

Funding in 2010–11

Land Protection Fund ($20 000)

Collaborators

- Rabbit Management Advisory Group
- Brian Cooke (Invasive Animals Cooperative Research Centre; University of Canberra)
- Susan Fuller and Grant Hamilton (Queensland University of Technology)

More information

Key publications

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

Berman, D, Robertshaw, J & 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. 395–9.

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

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

Project dates

July 2007 – 2013

Project leader

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Other staff in 2010–11

David Berman and David Aster

Objectives

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

Rationale

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

Initial challenge tests showed that different populations of rabbits around Australia had differing levels of resistance to RHDV. The level of resistance was correlated to rainfall, with populations from regions of intermediate rainfall having the highest resistance levels. As rabbits develop resistance, changes in the virus to overcome this resistance can also be expected. Further challenge tests with virus collected from South Australia over three years showed that field strains are maintaining virulence. The original release strain, however, is less effective in this population, causing a lower mortality and a longer survival time (Figure 32.1).

We are now conducting a series of challenge tests on wild and domestic rabbit populations to determine whether resistance does indeed have a genetic basis. If resistance is genetically based, each subsequent generation bred from survivors should have increasing resistance levels.

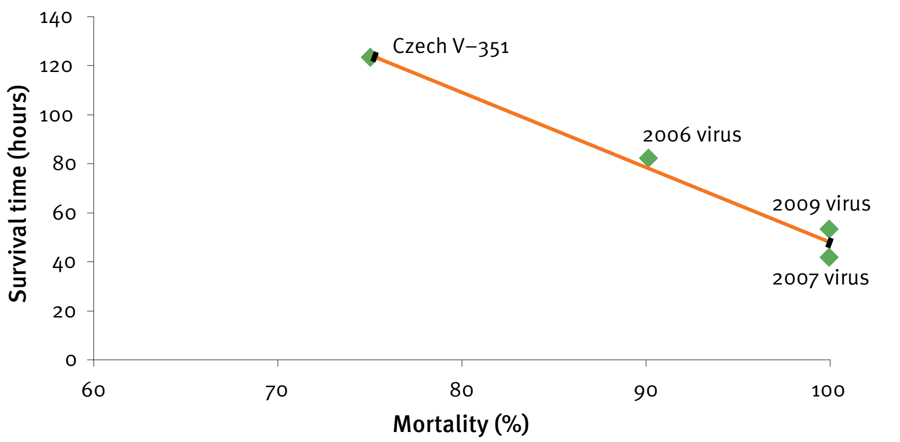

Figure 32.1 Mortality and survival time for rabbits orally challenged with the original release strain of RHDV (Czech V-351) and field strains collected in 2006, 2007 and 2009

Methods

We collect wild rabbits from Bulloo Downs in south-western Queensland, as well as domestic control rabbits, to form a parent generation (Generation 0). Prior to testing, offspring were bred from a random subset of Generation 0 to provide the next generation for testing (Generation 1). In challenge tests, each group of rabbits is administered a low oral dose of RHDV (1:25 dilution of stock solution, as the full dose would kill most of the rabbits regardless of whether they have resistance or not). Survivors of those trials are allowed to breed and their offspring is tested using the same procedures.

Progress in 2010–11

For the wild rabbits, mortality was 90% for the parent group (Generation 0) and 80% for the offspring (Generation 1). For the domestic control rabbits, mortality was 100% for Generation 0 and 95% for Generation 1.

From the six surviving wild rabbits, a new generation of young rabbits has been bred to be tested later in 2011. It is expected that this group (Generation 2) will have a lower mortality than the two previous generations.

Funding in 2010–11

Queensland Government

Collaborators

- Brian Cooke (Invasive Animals Cooperative Research Centre; University of Canberra)
- Greg Mutze, Ron Sinclair and John Kovalivski (Biosecurity SA)

More information

Key publications

Cooke, BD, Elsworth, PG, Berman, DM, McPhee, SR, Kovalivski, J, Mutze, GJ, Sinclair, RG & Capucci, L 2007, *Rabbit haemorrhagic disease: wild rabbits show resistance to infection with Czech strain 351 RHDV initially released in Australia*, Report submitted to Australian Wool Innovation and Meat and Livestock Australia, Invasive Animals Cooperative Research Centre, Canberra.

Story, G, Berman, D, Palmer, R & Scanlan, J 2004, 'The impact of rabbit haemorrhagic disease on wild rabbit (*Oryctolagus cuniculus*) populations in Queensland', *Wildlife Research* 31(2): 183–93.

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

33. Pest management chemistry

Project dates

Ongoing

Project leader

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Other staff in 2010–11

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

We provide chemical advice and support to pest management in Queensland and undertake toxicological and ecotoxicological investigations relating to the use of vertebrate pesticides using the laboratory and formulation facilities at the Health and Food Sciences Precinct at Coopers Plains.

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

Progress in 2010–11

Ecotoxicology

We completed determinations of 1080 (sodium fluoroacetate) residues in 70 fox baits for the Tasmanian Government Department of Primary Industries, Parks, Water and Environment for input into a model describing the degradation of 1080 baits in the environment. Further analyses will continue in 2011–12.

Forensic toxicology

Over the year, our laboratory performed 80 investigations relating to possible fluoroacetate poisoning, 43 relating to possible strychnine poisoning, 32 relating to possible anticoagulant poisoning and 5 relating to possible metaldehyde (molluscicide) poisoning. Most investigations related to domestic dogs and cats, but some involved wildlife (macropods). Our laboratory also conducted total iodine analysis on 17 samples relating to animal health.

Formulation chemistry

During the year our formulation facility produced 840 L of 1080 pig bait (36 g L^{-1}) solution in accordance with the upcoming APVMA registration. The department maintains a strong testing program to ensure that sodium fluoroacetate baiting in Queensland meets agreed standards. Testing of post-preparation sodium fluoroacetate solutions and meat baits continued throughout the year. Additional testing of sodium fluoroacetate and rodenticide formulations was undertaken for industry.

We provided further concentration data on a number of herbicide formulations used in the control of invasive weeds.

Funding in 2010–11

- Land Protection Fund ($165 000)
- Queensland Government
- Fee for service ($24 000)

34. Chemical registration: providing tools for invasive pest control

Project dates

Ongoing

Project leader

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Other staff in 2010–11

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 on 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 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. 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 with both 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 marketplace. As a consequence, investigations are normally restricted to likely crop and environmental residues, impact on the environment, and efficacy and safety in the use of a pesticide in a new situation or for a new pest. Project staff work with other scientists to ensure that data is available to address these issues and that any studies conducted for regulatory purposes meet APVMA requirements and guidelines.

Progress in 2010–11

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

- PER12202, obtained for the use of registered products containing glyphosate (360 g L^{-1} or 450 g L^{-1}), fluazifop (128 or 212 g L^{-1}) or flupropanate (745 g L^{-1}) as active ingredients to control tussock grasses (*Nasella* spp.) in non-crop situations
- PER12139, renewed for the use of registered products containing fluroxypyr (333 g L^{-1}), glyphosate (360 g L^{-1}), imazapyr (250 g L^{-1}), triclopyr (240 g L^{-1}) + picloram (120 g L^{-1}) or triclopyr (200 g L^{-1}) + picloram (100 g L^{-1}) as active ingredients to control pond apple (*Annona glabra*)
- PER12436, obtained for the use of registered products containing imazapyr (250 g L^{-1}), metsulfuron-methyl (600 g L^{-1}), picloram (43 g L^{-1} in a gel formulation) or triclopyr (600 g L^{-1}) as active ingredients to control gingers (*Hedychium* spp.) in non-crop situations
- PER11540, obtained for the use of registered products containing haloxyfop (540 g L^{-1}) as an active ingredient to control hymenachne (*Hymenachne* spp.) in non-agricultural areas, native vegetation, pasture and aquatic areas
- PER12497, renewed for the use of registered products containing imazapyr (250 g L^{-1}), metsulfuron-methyl (600 g L^{-1}) or triclopyr (240 g L^{-1}) + picloram (120 g L^{-1}) as active ingredients to control calotrope (*Calotropis procera*) in non-crop situations
- PER12520, obtained for the use of registered products containing 2,4-D (500 or 625 g L^{-1}), 2,4-D (300 g L^{-1}) + picloram (75 g L^{-1}), metsulfuron-methyl (600 g L^{-1}), triclopyr (300 g L^{-1}) + picloram (100 g L^{-1}) or triclopyr (300 g L^{-1}) + picloram (100 g L^{-1}) + aminopyralid (8 g L^{-1}) as active ingredients to control bitter weed (*Helenium amarum*) in pastures, stock routes, roadside verges and non-crop situations
- PER12729, renewed for the use of 1080 (sodium fluoroacetate) to control feral cats (*Felis catus*) in forests, pastures, and non-crop, pre-plant and fallow land
- PER12745, obtained for the use of alphachloralose to control any species of exotic bird not already established in Queensland that has the potential to become a pest.

An emergency permit (PER12644) for use of alphachloralose by authorised persons to control house crows (*Corvus splendens*) was also obtained.

Funding in 2010–11

- Queensland Government
- Land Protection Fund

1. Abbreviations

ANOVA	analysis of variance
APVMA	Australian Pesticides and Veterinary Medicines Authority
ARC-PPRI	Agricultural Research Council—Plant Protection Research Institute (South Africa)
CABI Europe–UK	CABI Europe – United Kingdom
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CWTA	Centre for Wet Tropics Agriculture
DAFF	(Australian Government) Department of Agriculture, Fisheries and Forestry
DEEDI	(Queensland Government) Department of Employment, Economic Development and Innovation
DERM	(Queensland Government) Department of Environment and Resource Management
DDMRB	Darling Downs – Moreton Rabbit Board
DNA	deoxyribonucleic acid
GPS	global positioning system
MLA	Meat and Livestock Australia
NRETAS	(Northern Territory Government Department of) Natural Resources, Environment, The Arts and Sport
ppmv	parts per million by volume
QMDC	Queensland Murray–Darling Committee
RCV-A1	rabbit calicivirus strain A1
RHDV	rabbit haemorrhagic disease virus
TWRC	Tropical Weeds Research Centre
WONS	Weed(s) of National Significance

2. Species

Scientific name	Common name
Acacia nilotica	prickly acacia
Acacia auriculiformis, A. catechu, A. deanei, A. farnesiana, A. glauca, A. ferruginea, A. latronum, A. leucophloea, A. mellifera, A. planifrons, A. pringlei, A. sutherlandii and *A. tortilis*	various acacia species
Aceria lantanae	lantana budmite
Actinote anteas	mikania butterfly
Actinote thalia pyrrha	mikania butterfly
Agonosoma trilineatum	bellyache bush jewel bug
Alcidodes sedi	mother-of-millions weevil
Alternanthera philoxeroides	alligator weed
Anacardium occidentale	cashew
Andropogon gayanus	gamba grass
Annona glabra	pond apple
Anomalococcus indicus	babul scale
Anredera cordifolia	Madeira vine
Aquila audax	wedge-tailed eagle
Azadirachta indica	neem
Basella alba	Ceylon spinach
Bryophyllum spp.	mother-of-millions
Cabomba caroliniana	cabomba
Calotropis procera and *C. gigantea*	calotrope (rubber bush)
Calycomyza lantanae	lantana leaf-mining fly
Canis lupus familiaris and *C. l. dingo*	wild dog
Carmenta ithacae	parthenium clear-wing moth
Carvalhotingis visenda	cat's claw creeper leaf-sucking tingid
Cascabela thevetia	Captain Cook tree (yellow oleander)
Cecropia peltata	Mexican bean tree
Cecropia palmata	trumpet tree
Cenchrus ciliaris	buffel grass
Chromolaena odorata	chromolaena (Siam weed)
Clidemia hirta	clidemia (Koster's curse)
Conotrachelus albocinereus	parthenium stem-galling weevil
Corvus coronoides	Australian raven
Corvus splendens	house crow
Cylindropuntia fulgida	coral cactus
Cylindropuntia kleinae	candle cholla
Cylindropuntia rosea	Hudson pear
Cyperus aromaticus	navua sedge

Scientific name	Common name
Dactylopius tomentosus	cochineal insect
Delonix regia	poinciana
Dereodus denticollis	leaf-feeding weevil
Echeveria spp.	echeveria
Epiblema strenuana	parthenium stem-galling moth
Felis catus	feral cat
Gmelina elliptica	badhara bush
Gymnocoronis spilanthoides	Senegal tea
Gymnorhina tibicen	Australian magpie
Haliastur sphenurus	whistling kite
Hedychium spp.	gingers
Helenium amarum	bitter weed
Hylaeogena jureceki	leaf-mining buprestid beetle
Hymenachne spp.	hymenachne
Hypocosmia pyrochroma	cat's claw creeper leaf-tying moth
Isturgia disputaria	semi lopper
Jatropha gossypiifolia	bellyache bush
Jatropha curcas	physic nut
Jatropha integerrima	peregrina
Jatropha multifida	coral plant
Jatropha podagrica	buddha belly plant
Kalanchoe blossfeldiana, K. crenata and *K. spathulata*	kalanchoe
Lantana camara	lantana
Leucaena leucocephala ssp. *glabrata*	leucaena
Limnocharis flava	limnocharis (yellow burhead)
Macfadyena unguis-cati	cat's claw creeper
Mangifera indica	mango
Mayaca fluviatilis	bog moss
Miconia calvescens, M. nervosa and *M. racemosa*	miconia
Mikania micrantha	mikania vine (mile-a-minute)
Milvus migrans	black kite
Mimosa pigra	mimosa
Nassella spp.	tussock grasses
Nassella tenuissima	Mexican feather grass
Neptunia plena and *N. oleracea*	water mimosa
Ophiomyia camarae	lantana herringbone leaf-mining fly
Opuntia tomentosa	velvety tree pear
Orobanche ramosa	branched broomrape

Scientific name	Common name
Oryctolagus cuniculus	rabbit
Osphilia tenuipes	mother-of-millions weevil
Parsonsia straminea	monkey rope vine (silk pod vine)
Parthenium hysterophorus	parthenium
Passiflora suberosa	corky passionflower
Phakopsora jatrophicola	jatropha rust fungus
Phenrica sp.	Madeira vine leaf beetle
Phycita sp.	leaf-webbing caterpillar
Phyla canescens	lippia
Piper nigrum	black pepper
Plectonycha correntina	Madeira vine leaf beetle
Prosopis pallida	mesquite
Puccinia lantanae	lantana rust
Puccinia xanthii var. *parthenii-hysterophorae*	parthenium summer rust
Puccinia spegazzinii	mikania rust
Ravenelia acacia-arabicae	prickly acacia gall-inducing rust
Ravenelia evansii	prickly acacia leaf rust
Scirtothrips aurantii	South African citrus thrips
Smilax australis	barbed wire vine
Sus scrofa	feral pig
Tecoma stans	yellow bells
Themeda quadrivalvis	grader grass
Uroplata girardi	lantana leaf-mining beetle
Varanus gouldii	Gould's goanna
Varanus varius	lace monitor
Verbena officinalis var. *africana* and var. *gaudichaudii*	verbena
Ziziphus mauritiana	chinee apple