Technical highlights

Invasive plant and animal research 2013–14

Queensland Government

CS4110 04/15

COVER PHOTO: Mindaye Teshome from the Ethiopian Forestry Research Institute collecting potential biocontrol agents on prickly acacia in Dire Dawa town in eastern Ethiopia

Contents

Introduction

This document provides a summary of the 2013–14 research program of the Invasive Plants and Animals Science group in Biosecurity Queensland. Our applied research program aims to better manage Queensland's worst weeds and pest animals, reducing their impacts on agriculture, the environment and the community.

Our work is undertaken at five centres across the state—Ecosciences Precinct (Dutton Park), Health and Food Sciences Precinct (Coopers Plains), Robert Wicks Pest Animal Research Centre (Toowoomba) and Tropical Weeds Research Centre (Charters Towers and South Johnstone). We also collaborate with numerous organisations within the state, interstate and overseas. Higher degree students are supported to work on several research projects in weed and pest animal management.

The research projects summarised in this document cover the development of effective control strategies and methods (e.g. biological control and herbicides), as well as improved knowledge of pest species' biology and assessment of pest impact. Notable achievements of the research program for 2013–14 are outlined below.

Invasive plant science

- Splatter guns, providing low-volume/high-concentration applications of herbicides, have been successfully used to treat bellyache bush with metsulfuron-methyl. Testing has now turned to prickly acacia and rubber vine. Spray misting of prickly acacia regrowth with herbicides is also showing great promise.
- Seed longevity is a major influence on the timing of follow-up control and is being determined for numerous weeds, including yellow oleander, mesquite, prickly acacia, chinee apple, parthenium, orange-flowering and pink-flowering lantana, Gamba grass, calotrope, leucaena, yellow bells, Captain Cook tree, neem, Navua sedge, Siam weed and stevia.
- Grader grass dominance results from frequent ecosystem disturbance, such as by fire. Spot applications of flupropanate are proving useful in the control of Gamba and perennial mission grass.
- Ground applications of two residual herbicides and cut stump treatment using glyphosate are providing high mortality rates in calotrope. This should lead to a revised minor use permit for its control.
- We continue to monitor progress towards eradication of the four tropical weeds and support field operations, providing information such as 140 days to flowering from seed for *Miconia micrantha*.
- Control techniques to enable eradication of red witchweed are being assessed in a field trial. Critical to their evaluation is the now successful extraction and identification of the abundant (over 10 000 per plant) and minuscule (200 microns) seed produced by this parasitic weed of grasses, including crops such as sugar cane, sorghum and corn.
- Water hyacinth appears to be one of the few aquatic weeds providing shelter to mosquitoes capable of carrying human diseases such as Ross River fever. This is being explored further experimentally.
- Host-specificity testing has been completed for biocontrol agents for Siam weed (chromolaena) and *Cyclindropuntia fulgida* var. *mamillata*. These are highly damaging agents and applications for field release will be submitted during 2014–15.
- Promising biocontrol agents are being assessed in quarantine at the Ecosciences Precinct for their host-specificity to bellyache bush, prickly acacia, cat's claw creeper, other *Cyclindropuntia* spp. and lantana.
- We are also assessing the host-specificity of a scale insect—a potential agent for prickly acacia—in field experiments on Australian plants in India. The scale develops and feeds on non-target plants in the Brisbane quarantine, but this appears to be an artefact of the laboratory environment as the scale has so far been host-specific in the field.
- Overseas explorations and collaborations have resulted in new agents for bellyache bush, prickly acacia and mikania being introduced to the Brisbane quarantine for host-specificity testing during 2014–15.
- Our overseas work includes helping other countries, such as Papua New Guinea and Vanuatu, to manage weeds. This is an important form of aid from Australia in alleviating poverty in developing countries where weeds directly affect the economic livelihood of subsistence farmers. It also reduces the risk of weeds such as Siam weed and mikania spreading to Australia, and provides us with management strategies for those weeds, including biocontrol agents for which there is already a large amount of impact assessment and host-specificity testing. International collaboration is a necessary and efficient way of undertaking weed biocontrol.

Pest animal management

- Monitoring the ranging behaviour of wild dogs with satellite tracking collars in peri-urban areas has revealed adaptable habitat use, with breeding and rearing of pups within a few hundred metres of built-up areas. Data indicate they feed mostly on native prey such as bandicoots and wallabies, but are pests because they attack domestic stock and pets, and are a threat to people, particularly children. Their management is not straightforward, but testing of ejectors suggests they may be useful.
- In rural areas grazed by cattle, calf loss studies on a large number of properties suggests that baiting with 1080 can at times be counter-productive and that frequent, preventative baiting is far more effective at controlling dog impact than reactive, occasional baiting.
- In areas grazed by sheep, landholders are turning to cluster fences to manage both wild dog predation and overgrazing by kangaroos. The rationale is that, if immigration can be stopped, graziers can control their closed population of pests. We are monitoring kangaroo and wild dog abundance and pasture condition inside and outside a large cluster fence in south-western Queensland.

- Feral pig abundance has been recorded on annual aerial surveys for kangaroos since the early 1990s. These data are being related to rainfall, estimates of pasture biomass, harvesting and 1080 baiting in a model to predict future population fluctuations and the impact of control.
- Analysis of stomach contents of feral cats, foxes and pigs in southern Queensland reveals an increasing degree of omnivory and declining carnivory (from cats to foxes to pigs) in grain production environments.
- We are now studying the distribution, impacts and ranging behaviour of chital deer in northern Queensland. This is in response to their relatively recent spread and increase in abundance, despite having a restricted distribution for over 100 years. We have also run workshops on the management of peri-urban populations of four deer species, which are becoming increasingly problematic.
- The ranging behaviour of five chital deer near Charters Towers was monitored with satellite tracking collars. Over a 6-month period, the deer ranged over areas of 800 to 4500 ha across a number of grazing properties. These data are being analysed to describe their habitat use. The study is now being extended to examine their diet, broadscale distribution and control.
- Long-term data on the demography of rabbit populations in western and south-eastern Queensland are being modelled to better understand their impact on livestock production and the efficacy of control through warren-ripping. Complementing this work is the study of the potential impact of rabbits to horticulture.
- The apparent increase of rabbits in northern Queensland is being investigated through a study of their ecology. Initial data indicate these rabbits live almost entirely above ground, making control more difficult.
- The benign rabbit calicivirus that provides partial immunity to RHDV was recorded in two of seven regions in south-eastern Queensland. Conventional control methods will be particularly important in these areas. The release of a new strain of RHDV by the Invasive Animal Cooperative Research Council (CRC)—likely at the earliest in 2016—to overcome the protection afforded by the non-pathogenic calicivirus will benefit these areas. The impact of this release will be monitored.

Research services

- At Coopers Plains, our chemistry group produces 1080 solution for use in pig, dog and fox baits. The group also tests various poisons as possible causes of death for animal mortalities reported by the public. In addition, testing for residues in baits is carried out to quantify how long chemicals last in the environment.
- Twenty-two minor use permits were obtained for the new or altered weed species, herbicides, application methods, and situations or environments from the Australian Pesticides and Veterinary Medicines Authority.

Funding, collaboration and research priorities

In the 2013–14 financial year, Biosecurity Queensland's Invasive Plant and Animal Science program received funding from a number of sources. Queensland Government base funds provided $1.8 million, contributions from the Land Protection Fund amounted to $1.8 million and funding under contracts with external partners totalled $0.7 million (see page 24). Notable funding bodies for the latter were the Australian Government, Meat and Livestock Australia (MLA) and the Invasive Animal CRC.

Our research program for 2013–14 was endorsed by the Research Review Committee—a group of senior scientific, operations and policy staff from Biosecurity Queensland. The committee critically reviews proposed project outcomes and allocated investments, and makes recommendations on strategic priorities, existing research gaps and projects due for scientific review. We will be seeking input on research priorities from Queensland local governments, natural resource management bodies and other stakeholders through a series of regional workshops.

Further information

We encourage you to visit the Invasive Plant and Animal Science web pages on the Department of Agriculture and Fisheries (DAF) website (www.biosecurity.qld.gov.au) for further information. Journal articles and scientific reports can also be obtained by emailing project leaders (see page 25–26). In addition, you can browse through our recent scientific publications in the fully searchable eResearch Archive at www.daf.qld.gov.au/research, 'publications and datasets' link.

Part 1: Invasive plant science

1. Weed seed dynamics

Project dates

August 2007 – June 2020

Project team

Shane Campbell, Christopher Crowley and Emma Carlos

Project summary

There are many declared weeds for which we know very little about their seed ecology, particularly their longevity. In this project, seed longevity of priority weeds—including yellow oleander, mesquite, prickly acacia, chinee apple, parthenium, orange-flowering and pink-flowering lantana, Gamba grass, calotrope, leucaena, yellow bells, Captain Cook tree, neem and stevia—is being investigated in two different soil types (black clay and river loam), under two grass cover conditions (grassed and non-grassed) and at four burial depths (0, 2.5, 10 and 20 cm).

Besides continuing to retrieve seed lots of the various weeds at predetermined intervals and undertaking viability testing, a key focus of this project over the last 12 months has been analysing the results of weeds whose seed has expired. A scientific paper has been completed on calotrope and is currently undergoing internal review. Calotrope was found to have highly germinable seed that resulted in seed banks expiring within 15 to 24 months after burial, due to rapid germination in the field following favourable rainfall conditions. Analysis of two other weeds (chinee apple and Captain Cook tree) with short-lived seed banks has also been completed and draft scientific papers prepared.

Collaborators

Bob J Mayer (Senior Biometrician, DAF), Faiz Bebawi

Key publications

Bebawi FF, Campbell SD & Mayer RJ 2012, Persistence of bellyache bush (*Jatropha gossypiifolia* L.) soil seed banks, *The Rangeland Journal* 34, 429–438.

2. Best practice management of wet tropics weeds

Project dates

January 2009 – June 2015

Project team

Melissa Setter, Stephen Setter, Wayne Vogler and Emma Carlos

Project summary

The Wet Tropics bioregion of northern Queensland is of high economic, social and environmental value. Numerous weed species threaten to degrade these values unless well managed.

The research directly supports on-ground weed management by investigating seed longevity, time to reproductive maturity, dispersal mechanisms and control options for priority species.

Navua sedge (*Cyperus aromaticus*)

A final field trial to refine rates for the control of Navua sedge using the herbicide Sempra™ (halosulfuron 750 g/kg) has been completed, and a draft paper written. Halosulfuron was effective at quite low rates, but only in conjunction with a comprehensive monitoring and re-treatment program. This information has been supplied to Nufarm to support a case for registration of Sempra™ for control of Navua sedge.

An ongoing seed burial trial suggests that Navua sedge has a highly persistent seed bank with an average of 15% viability (across different depths) recorded after 10 years. Testing of 15-year-old seed will be undertaken in 2017.

Bogmoss (*Myaca fluviatilis*)

A time exposure herbicide trial on submerged bog moss has been completed and the findings are being used to develop a final shadehouse trial to test a few herbicides on emergent bog moss (i.e. growing on both the surface and submerged).

Seed persistence in water (several species)

Laboratory trials on seeds of Navua sedge, leuceana and hymenachne have shown that they all retained some viability after 14 weeks immersion in salt, brackish and fresh water. Neem and bellyache bush will be the next species to undergo testing.

Collaborators

BiosecurityQueensland officers, Biosecurity Queensland research (other officers/centres), Far North Queensland Regional Organisation of Councils, Cairns Regional Council, Cassowary Coast Regional Council, Tablelands Regional Council, land managers

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

Project dates

June 2010 – May 2015

Project team

Shane Campbell and Christopher Crowley

Project summary

This project is part of a larger, collaborative MLA-funded research program aimed at improving our understanding of the distribution, rate of spread, invasiveness, other ecological aspects and control of calotrope. Biosecurity Queensland is focusing on improving control options, with Charles Darwin University and the Northern Territory Department of Land Resource Management researching its ecology. Control research implemented to date includes:

- testing cut stump, frill, basal bark and soil-applied herbicides to provide practical options for control of isolated plants
- screening and testing rates of foliar herbicides to provide more options
- evaluation of aerial application of Graslan* (tebuthiuron) for broadscale control in appropriate areas (in conjunction with Dow AgroSciences)
- testing the susceptibility of calotrope to mechanical control through cutting experiments and evaluation of demonstration sites.

Over the past 12 months, testing of ground applications of 2 residual herbicides containing the active ingredients tebuthiuron and hexazinone has confirmed that they can provide high mortality at rates currently registered for other woody weeds. Glyphosate is also proving highly effective as a cut stump treatment. Approval will be sought for all these treatments to be included in a revised minor use permit for calotrope once appropriate rates have been finalised.

Collaborators

MLA, Charles Darwin University, Northern Territory Department of Land Resource Management, The University of Queensland, Dow AgroSciences, Peter and Ann Woollett (landholders), John Nelson (landholder)

Key publications

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

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

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

Project dates

January 2007 – June 2016

Project team

K. Dhileepan, Di Taylor and Liz Snow

Project summary

Host range tests for Jatropha rust (*Phakopsora arthuriana*) by CABI (UK) is nearing completion. Testing was completed for 38 of the 39 test plant species. Seeds of the last remaining test plant species (*Endospermum medullosum*), sourced from Vanuatu, have been exported to CABI. In quarantine tests, the Jatropha leaf rust sporulated on two non-target species—*Aleurites moluccana*, rated as weakly susceptible, and *Beyeria viscosa*, rated as moderately susceptible. There was no sporulation on the related test plant species, *A. rockinghamensis*. Host-range tests for *B. leschenaultii* and *E. medullosum* are in progress. To further ascertain the susceptibility of non-target plant species to the Jatropha rust, a susceptibility trial will be conducted involving four non-target plants (*A. moluccana, B. viscosa*, *A. rockinghamensis* and *Jatropha curcas*) and bellyache bush (*Jatropha gossypiifolia*) under natural field conditions in Trinidad (as the Trinidad strain was used in host-range tests) from November 2014 to January 2015.

Permits to import the Jatropha leaf-miner (*Stomphastis* sp.) from Bolivia and Peru were obtained, and the insect was imported in November 2014. Required host (bellyache bush) and test plants are being procured for colony establishment and host-specificity testing in quarantine.

Collaborators

Tanya Scharaschkin (Queensland University of Technology), Stefan Neser (Plant Protection Research Institute, Pretoria, South Africa), Marion Seier, Kate Pollard (CABI, UK), Damian Rumiz (Noel Kempff Mercado Museo de Historia Natural, Santa Cruz, Bolivia), Diana Silva Davilla (Museo de Historia Natural, Lima, Peru)

Key publications

Heard TA, Dhileepan K, Bebawi F, Bell K & Segura R 2012, *Jatropha gossypiifolia L.*—bellyache bush, pp. 324–333, in *Biological control of weeds in Australia: 1960 to 2010* (eds M Julien, RE McFadyen & J Cullen), CSIRO Publishing, Melbourne.

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.

Bebawi FF, Lockett CJ, Davis KM & Lukitsch BV 2007, Damage potential of an introduced biological control agent *Agonosoma trilineatum* (F.) on bellyache bush (*Jatropha gossypiifolia* L.), *Biological Control* 41(3): 415–22.

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.

5. Biological control of prickly acacia (*Vachellia nilotica* ssp. *indica*)

Project dates

January 2007 – June 2016

Project team

K Dhileepan, Di Taylor and Kumaran Nagalingam (from Jan 2014)

Project summary

Host-specificity testing for the scale insect (*Anomalococcus indicus*) and the green leaf-webber (*Phycita* sp. B) sourced from India is in progress under quarantine. For the scale insect (*A. indicus*), 58 non-target species have been tested. In no-choice trials, mature gravid females developed on 13 non-target test plant species, with high numbers of mature females developing on four non-target species and low numbers of mature females developing in some replicates on nine non-target species. This contradicts surveys in the native range where the scale is found only on prickly acacia. In choice trials, crawlers showed a significant preference for prickly acacia over the non-target species. To resolve this apparent lack of host-specificity in an artificial laboratory environment, a field choice trial involving prickly acacia and *Neptunia major* is in progress in India. Preparations for a choice trial involving four non-target test plant species *(Acacia falcata, Vachellia sutherlandii, N. major* and *N. monosperma)* under field conditions in India are underway. A colony of the leaf-weevil (*Dereodus denticollis*) could not be established in the quarantine due to difficulties in getting oviposition. A colony of a second leaf-webbing species (*Phycita* sp. B) has been established in quarantine and no-choice host-specificity tests are in progress. Future research will focus on the importation and colony establishment of a leaf-weevil (*D. denticollis*) and leaf-beetle (*Pachnephorus* sp.) from India.

Collaborators

A Balu, S Murugesan (Institute of Forest Genetics and Tree Breeding), Stefan Neser (Plant Protection Research Institute, Pretoria, South Africa), Marion Seier, Kate Pollard (CABI, UK), A Raman (Charles Sturt University, Orange, New South Wales)

Key publications

Khan AN, Raman A, Dhileepan K & Hodgkins DS 2014, Feeding behaviour of *Anomalococcus indicus* (Hemiptera: Lecanodiaspididae) with supplementary biological notes and biological management of the invasive *Vachellia nilotica indica* (Fabales: Mimosoideae) in north-eastern Australia, *Annales de la Société entomologique de France* 49: 476–492.

Taylor DBJ & Dhileepan K 2013, Life history of babul scale *Anomalococcus indicus* (Hemiptera: Lecanodiaspididae), a potential biological control agent for prickly acacia in Australia, *Biocontrol Science and Technology* 23: 1373–1386.

Shivas RG, Balu A, Singh S, Ahmed SI & Dhileepan K 2013, *Ravenelia acaciae-arabicae* and *Ravenelia evansii* are distinct species on *Acacia nilotica* subsp. *Indica*, *Australasian Mycologist* 31: 31–37.

Dhileepan K, Balu A, Senthilkumar P, Murugesan M & Shivas R 2013, Survey and prioritisation of potential biological control agents for prickly acacia (*Acacia nilotica* ssp. *indica*) from southern India, *Biocontrol Science and Technology* 23: 646–664.

6. Biological control of invasive vines (*Dolichandra unguis-cati* and *Anredera cordifolia*)

Project dates

July 2001 – June 2015

Project team

K Dhileepan and Liz Snow

Project summary

For cat's claw creeper, 42 000 leaf-mining beetles (*Hylaeogena jureceki*) have been released across 70 release sites in Queensland. This includes about 2 000 adults released over 50 sites from July 2013 to June 2014. In addition, starter colonies of the beetle have also been supplied to various Landcare groups, community groups and local government. The beetle has become established in the majority of release sites, and is likely to become more widespread over time. The field release of the beetle will continue for one more year. Future research will focus on monitoring the establishment and spread of the leaf-mining beetle (*H. jureceki*), the leaf-tying moth (*Hypocosmia pyrochroma*) and the leaf-sucking tingid (*Carvalhotingis visenda)*.

For Madeira vine, 35 000 leaf-feeding beetles (*Plectonycha correntina*) have been released at 86 sites in Queensland since May 2011. Mass rearing and field release of the leaf-feeding beetle finished around spring 2013. The beetle has established and is persisting at 58% of the release sites, but there is no evidence of any widespread dispersal of the beetle in the field. There are no other prospective biological control agents for Madeira vine (based on native range surveys in South America).

Collaborators

Tanya Scharaschkin (Queensland University of Technology), Anthony King and Stefan Neser (Plant Protection Research Institute, Pretoria, South Africa), Marion Seier, Kate Pollard (CABI, UK), Robert Barreto (Universidade Federal de Vicosa, Brazil), Gympie & District Landcare Group, South Burnett Regional Council, Queensland Parks and Wildlife Service, Burnett Mary Regional Group, Moggill Creek Catchment Group, Gold Coast City Council, Brisbane City Council, SEQ Catchments, New South Wales Environmental and Aquatic Weed Biological Control Taskforce

Key publications

Dhileepan K, Taylor DBJ, McCarthy J, King A & Shabbir A 2013, Development of cat's claw creeper leaf-tying moth *Hypocosmia pyrochroma* (Lepidoptera: Pyralidae): implications for establishment as biological control agent in Australia and South Africa, *Biological Control* 67: 194–202.

Dhileepan K, Taylor D, Treviño M & Lockett C 2013, Cat's claw creeper leaf-mining beetle *Hylaeogena jureceki* Obenberger (Coleoptera: Buprestidae), a host specific biological control agent for Dolichandra unguis-cati (Bignoniaceae), Australian Journal of Entomology 52: 175–181.

Dhileepan K 2012, *Macfadyena unguis-cati* (L.) A.H. Gentry—cat's claw creeper, pp. 351–359, in *Biological control of weeds in Australia: 1960 to 2010* (eds M Julien, RE McFadyen & J Cullen), CSIRO Publishing, Melbourne.

Dhileepan K, Treviño M, Bayliss D, Saunders M, McCarthy J, Shortus M, Snow EL & Walter GH 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: 58–62.

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

Project dates

July 2004 – June 2015

Project team

K Dhileepan, Segun Osunkoya and Kelli Pukallus

Project summary

Surveys of parthenium biocontrol agents were conducted at 16 sites in central Queensland in April 2014 and at three sites in northern Queensland in May 2014.

In central Queensland, the *Carmenta* moth was widespread, occurring in all sampling sites with parthenium (30% incidence at locations within sites in Gracemere, 60% in Carfax, 8% in Wycarbah, 55% in Apis Creek, 35% in Overflow, 2% in Morebridge, 6% in Gaylong, 80% in Gordon Road, 20% in Wyntoon, 40% in Sandhurst Bridge, 47% in Springsure, 50% in Rolleston and 12% in Moleyamber Creek). Very abundant populations of the seed-feeding *Smicronyx* weevil were also seen in several sites (e.g. Moleyamber Creek, Hutton Creek, Clermont, Rolleston, Sandhurst Bridge and Wyntoon). Other agents were either absent or were present at very low abundance.

In northern Queensland, incidence of the stem-galling *Epiblema* moth and the parthenium summer rust remained low in all three sites (Plain Creek, Cardigan Station and Bivouac Junction). The seed-feeding *Smicronyx* weevil, the stem-boring *Listronotus* weevil, the leaf-mining *Bucculatrix* moth and the root-feeding *Carmenta* moth were the other agents recorded at these sites.

The *Smicronyx* weevil from central and northern Queensland has been redistributed to a parthenium trial site (Helidon's Spa) in south-eastern Queensland. The winter rust was redistributed from south-eastern Queensland to western Queensland (St George).

Collaborators

Steve Adkins (The University of Queensland), Mariano Trevino

Key publications

Dhileepan K & McFadyen RE 2012, *Parthenium hysterophorus* L.—parthenium, pp. 448–462, in *Biological control of weeds in Australia: 1960 to 2010* (eds M Julien, RE McFadyen & J Cullen), CSIRO Publishing, Melbourne.

Dhileepan K 2009, Managing *Parthenium hysterophorus* across landscapes: limitations and prospects, pp. 227–260, in *Management of Invasive Weeds* (ed. S Inderjit), Invading Nature—Springer Series in invasion ecology vol. 5, Springer Science.

Dhileepan K & Strathie L 2009, 20. *Parthenium hysterophorus*, pp. 272–316, in *Weed biological control with arthropods in the* tropics: towards sustainability (eds R Muniappan, DVP Reddy & A Raman), Cambridge University Press, Cambridge, UK.

8. *Biocontrol of Cylindropuntia* spp.

Project dates

March 2009 – 30 June 2015

Project team

Michael Day and Peter Jones

Project summary

The cactus *Cylindropuntia* spp. are native to tropical America. The group includes *Cylindropuntia rosea* (Hudson pear) and *C. tunicata* (both of which are found in Queensland and are Class 1 weeds) and *C. fulgida* and *C. imbricata* (which are more widespread in Queensland and are Class 2 weeds). *Cylindropuntiua rosea* was approved as a target for biocontrol in Australia in 2008 and the remaining *Cylindropuntia* spp. were approved as targets in 2013. Seven biotypes of *Dactylopius tomentosus*, including one which had already been released in Australia in 1925 to control *C. imbricata*, were tested to determine their specificity and their effectiveness against each of the eight naturalised species of *Cylindropuntia* in Australia.

All biotypes were host-specific to the genus *Cylindropuntia*. The *D. tomentosus* biotype released in South Africa was very effective against *C. fulgida* var. *mamillata* and an application seeking approval for its field release is being prepared. The biotype collected from *C. rosea* in Mexico was ineffective on *C. rosea* in Australia and so the colony in quarantine was destroyed. Trials assessing efficacy and population growth of the four new biotypes of *D. tomentosus* collected from the United States are still in progress. All biotypes appear to be damaging to at least one of the *Cylindropuntia* spp.

Collaborators

New South Wales Department of Primary Industries, Plant Protection Research Institute 'South Africa' local governments in central and western Queensland

Key publications

Holtkamp, RH 2012, *Cylindropuntia imbricata* (Haw.) F. M. Knuth—rope pear *Cylindropuntia rosea* (DC.) Backeb.—Hudson pear, in *Biological Control of Weeds in Australia*, (eds M Julien, R McFadyen & JM Cullen), CSIRO Publishing, Melbourne, pp. 198–202.

Mathenge CW, Holford P, Hoffmann JH, Spooner-Hart R, Beattie GAC & Zimmermann HG 2009, The biology of *Dactylopius tomentosus* (Hemiptera: Dactylopiidae), *Bulletin of Entomological Research* 99(6): 551–9.

Mathenge CW, Holford P, Hoffmann JH, Zimmermann HG, Spooner-Hart R & Beattie GAC 2009, Distinguishing suitable biotypes of *Dactylopius tomentosus* (Hemiptera: Dactylopiidae) for biological control of *Cylindropuntia fulgida* var. *fulgida* (Caryophyllales: Cactaceae) in South Africa, *Bulletin of Entomological Research* 99(6): 619–27.

9. Biocontrol of *Lantana camara*

Project dates

July 1996 – June 2014

Project team

Michael Day and Natasha Riding

Project summary

Lantana is a serious weed of grazing, forestry and conservation areas. It is found throughout coastal and subcoastal areas of eastern Australia—from the Torres Strait islands in the north to the Victorian border in the south. Lantana can be controlled using chemicals, machinery and fire, but some of these methods are not viable in forestry or conservation areas or are not economically feasible. Biological control is therefore seen as the only viable option in many areas. Although biocontrol has been in progress since 1914, recent research has emphasised the need to target agents that damage specific parts of the plant or the different climatic areas in which lantana grows. This project aims to improve biocontrol of lantana in Queensland through active collaboration with PPRI in South Africa, CABI Europe–UK, New South Wales Biocontrol Taskforce and local councils and landcare groups. Initial host-specificity testing of the rust *Puccinia lantanae* by CABI has been completed. However, additional tests need to be conducted on *Verbena officinalis* var. *gaudichaudii* and species in the family Acanthaceae to clarify specificity. Seeds and plants of the extra species have been sent to CABI and additional testing has commenced. Following approval, the budmite *Aceria lantanae* has been released widely in south-eastern Queensland and galls have been seen at up to 15 sites. Releases have also commenced in northern Queensland. Gall presence and persistence in the field depends on weather conditions and whether plants are in flower.

Collaborators

CABI Europe–UK, Plant Protection Research Institute (South Africa), New South Wales Weed Biocontrol Taskforce, Queensland Parks and Wildlife Services, local governments in coastal and subcoastal Queensland

Key publications

Day, M 2012, *Lantana camara* L.—lantana, in *Biological Control of Weeds in Australia* (eds M Julien, R McFadyen & J Cullen), CSIRO Publishing, Melbourne, pp. 334–46.

Day, MD & Zalucki, MP 2009, *Lantana camara* Linn. (Verbenaceae), in *Biological control of tropical weeds using arthropods* (eds R Muniappan, GVP Reddy & A Raman), 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.

10. Biocontrol of *Chromolaena odorata*

Project dates

July 2011 – June 2015

Project team

Michael Day and Natasha Riding

Project summary

Chromolaena odorata was first reported in Queensland in 1994 and is also present in the Australian territories, Christmas and Cocos islands. It was the target of a national cost-share eradication program until 2013. However, it was approved as a target for biocontrol in 2011, following several reviews. The gall fly *Cecidochares connexa* is deemed a host-specific biocontrol agent, having been tested in 4 countries against a total of 81 species, representing 18 families, including 23 species in the Asteraceae. The gall fly was subsequently released in several countries (including Papua New Guinea, Indonesia, Micronesia and Timor Leste), where it is controlling or aiding the control of chromolaena. It was imported into quarantine at the Ecosciences Precinct in February 2012, and testing against species in the Eupatorieae commenced immediately. Twenty species in the Eupatorieae were tested in choice-minus-the-host plant trials, with some larvae completing development to adult on *Praxelis clematidea*. Further tests determined that populations of the gall fly could not be sustained on *P. clematidea* and that the gall fly shows a preference for chromolaena over *P. clematidea*. Furthermore, field observations in Palau found no gall formation on *P. clematidea*. An application seeking its release will be submitted to Australian Quarantine and Inspection Service.

Collaborators

National Agricultural Research Institute (Papua New Guinea), Bureau of Agriculture (Palau)

Key publications

Day MD, Bofeng I & Nabo I 2013, Successful biological control of *Chromolaena odorata* (Asteraceae) by the gall fly *Cecidochares connexa* (Diptera: Tephritidae) in Papua New Guinea, in *Proceedings of the XIII International Symposium on Biological Control of Weeds* (eds Y Wu, T Johnson, S Sing, S Raghu, G Wheeler, P Pratt, K Warner, T Center, J Goolsby & R Reardon), Forest Health Technology Enterprise Team, Morgantown, WV, pp. 400–408.

Day MD, Brito AA, da Costa Guterres A, da Costa Alves AP, Paul T & Wilson CG 2013, Biocontrol of *Chromolaena odorata* in Timor Leste, in *Proceedings of the Eighth International Workshop on Biological Control and Management of* Chromolaena odorata *and other Eupatorieae* (eds C Zachariades, LW Strathie, MD Day & R Muniappan), ARC-PPRI, Pretoria, pp. 134–140.

Day M & McFadyen RC 2012, *Chromolaena odorata* (L.) King and Robinson—chromolaena, in *Biological control of weeds in Australia* (eds M Julien, R McFadyen & J Cullen), CSIRO Publishing, Melbourne, pp. 162–169.

11. Biological control of parkinsonia (*Parkinsonia aculeata*)

Project dates

March 2013 – March 2015

Project team

Kelli Pukallus and Judy Clark

Project summary

This collaborative project with CSIRO involves the mass rearing, releasing and monitoring of *Eueupithecia cisplatensis* (UU) for the biological control of parkinsonia within Queensland. UU, a leaf-feeding geometrid caterpillar from Argentina, defoliates the leaflets within its month-long life cycle.

Releases commenced in northern Queensland from the Tropical Weeds Research Centre colony in early 2013, but have expanded into central Queensland. To date, 779 adults, 43 000 pupae and 227 220 larvae have been released across 30 sites. Release sites cover various terrains and climatic conditions, including inland, open woodlands, coastal and riparian areas.

Field establishment has been hampered by predation of larvae by ants, wasps and spiders. Various release techniques were tried to overcome the predation. Pupal releases have proven to be the best method, as pupae are easy to transport and release, they persist at a site longer than other life stages and they have shown the best signs of establishment of UU.

The formation of consistent monitoring techniques within the release sites has allowed reliable observations of various larval stages. Seven sites in northern Queensland were sampled, with five found to have UU larvae. Conditions at the sites vary seasonally, with UU numbers declining over the winter and other drier months. Persistence over these periods at monitoring sites is unknown at this stage.

Collaborators

Andrew White, Gio Fichera, Tim Heard, Raghu Sathyamurthy (CSIRO Brisbane), Marina Wall (Three Rivers), Russell Bailey (Isaac Regional Council), Queensland Parks and Wildlife Services, Michelle Janes (DAF Emerald).

12. Improving weed management in Papua New Guinea

Project dates

January 2013 – June 2015

Project leader

Michael Day

Project summary

Weeds are a major concern for many Pacific island countries, including Papua New Guinea (PNG), and some pose a genuine biosecurity risk for Queensland through deliberate or natural spread. Many of these weeds—such as *Chromolaena odorata*, *Clidemia hirta*, *Mikania micrantha* and *Mimosa pigra*—are Class 1 weeds in Queensland. Other important invasive species in PNG include water hyacinth, water lettuce and *Mimosa diplotricha*, which are all Class 2 weeds in Queensland.

Assisting PNG to manage their weeds reduces the spread of these weeds and decreases their risk of entry into Queensland. Agents to control *Mimosa pigra* (Class 1) will be introduced from Australia, while biocontrol agents for other weeds such as mikania, chromolaena, water hyacinth, water lettuce and *Mimosa diplotricha* will be redistributed around PNG in areas where they are not already present. This project is supporting efforts to eradicate *Miconia calvescens* (Class 1 in Queensland) and parthenium (Class 2 in Queensland) from PNG. The seed-feeding bruchids (*Acanthoscledies* spp.) were introduced into PNG in 2014 from Australia to control *Mimosa pigra*, and agents for mikania, chromolaena and water hyacinth were redistributed into some areas where they were not already present. Workshops were conducted in 2013 and 2014, and formal training in various aspects of weed biocontrol will continue to be provided to local staff as required.

Collaborators

National Agriculture and Quarantine Inspection Authority, National Agricultural Research Institute, PNG Oil Palm Research Association, Secretariat of the Pacific Community

Key publications

Day MD, Bofeng I & Nabo I 2013, Successful biological control of *Chromolaena odorata* (Asteraceae) by the gall fly *Cecidochares connexa* (Diptera: Tephritidae) in Papua New Guinea, in *Proceedings of the XIII International Symposium on Biological Control of Weeds* (eds Y Wu, T Johnson, S Sing, S Raghu, G Wheeler, P Pratt, K Warner, T Center, J Goolsby & R Reardon), Forest Health Technology Enterprise Team, Morgantown, WV, pp. 400–408.

Day M & McFadyen RC 2012, *Chromolaena odorata* (L.) King and Robinson—chromolaena, in Biological control of weeds in Australia (eds M Julien, R McFadyen & J Cullen), CSIRO Publishing, Melbourne, pp. 162–169.

Day MD, Kawi AP & Ellison CA 2013, Assessing the potential of the rust fungus *Puccinia spegazzinii* as a classical biological control agent for the invasive weed *Mikania micrantha* in Papua New Guinea, *Biological Control* 67: 253–261.

Day MD, Kawi A, Kurika K, Dewhurst CF, Waisale S, Saul Maora J, Fidelis J, Bokosou J, Moxon J, Orapa W & Senaratne KAD 2012, *Mikania micrantha* kunth (Asteraceae) (mile-a-minute): its distribution and physical and socio economic impacts in Papua New Guinea, *Pacific Science* 66: 213–223.

13. Improving weed management in Vanuatu

Project dates

November 2011 – October 2014

Project leader

Michael Day

Project summary

Weeds are a major concern for many Pacific island countries, including Vanuatu, and some pose a genuine biosecurity risk for Queensland through deliberate or natural spread. Many of these weeds, such as *Mikania micrantha*, are Class 1 weeds in Queensland. Other important invasive species in Vanuatu include water hyacinth, water lettuce, parthenium and *Mimosa diplotricha*, which are all Class 2 weeds in Queensland.

Assisting Vanuatu to manage their weeds reduces the spread of these weeds and decreases their risk of entry into Queensland. Agents to control parthenium, water hyacinth (Class 2 in Queensland) and cat's claw creeper (Class 3 in Queensland) will be introduced from Australia, while biocontrol agents for other weeds such as mikania, water lettuce and *Mimosa diplotricha* will be redistributed around Vanuatu in areas where they are not already present. This project supports the eradication of parthenium from islands where it is feasible to do so. A second water hyacinth beetle was introduced into Vanuatu in 2013 and the parthenium beetle was introduced in 2014 to control their respective targets, while mikania rust, a water lettuce beetle and the first water hyacinth beetle were redistributed into areas where they were not already present. Field trips to other islands were conducted in 2013 and 2014, and training in various aspects of weed biocontrol was conducted with regional staff.

Collaborators

Biosecurity Vanuatu, Secretariat of the Pacific Community

Key publications

Day M 2012, *Mikania micrantha* kunth—mile-a-minute, in Biological control of weeds in Australia (eds M Julien, R McFadyen & J Cullen), CSIRO Publishing, Melbourne, pp. 368–372.

Day MD, Kawi AP, & Ellison CA 2013, Assessing the potential of the rust fungus *Puccinia spegazzinii* as a classical biological control agent for the invasive weed *Mikania micrantha* in Papua New Guinea, *Biological Control* 67: 253–261.

Day MD, Kawi AP, Fidelis J, Tunabuna A, Orapa W, Swamy B, Ratutini J, Saul-Maora J & Dewhurst CF 2013, Biology, field release and monitoring of the rust *Puccinia spegazzinii* de Toni (*Pucciniales: Pucciniaceae*), a biocontrol agent of *Mikania micrantha* Kunth (Asteraceae) in Papua New Guinea and Fiji, in *Proceedings of the XIII International Symposium on Biological Control of Weeds* (eds Y Wu, T Johnson, S Sing, S Raghu, G Wheeler, P Pratt, K Warner, T Center, J Goolsby & R Reardon), Forest Health Technology Enterprise Team, Morgantown, WV, pp. 211–217.

Day MD, Kawi A, Kurika K, Dewhurst CF, Waisale S, Saul Maora J, Fidelis J, Bokosou J, Moxon J, Orapa W & Senaratne KAD 2012, *Mikania micrantha* kunth (Asteraceae) (mile-a-minute): its distribution and physical and socio economic impacts in Papua New Guinea, *Pacific Science* 66: 213–223.

14. Gauging field efficacy of biocontrol agents on *Parthenium hysterophorus*

Project dates

July 2013 – June 2016

Project team

Olusegun Osunkoya, Christine Perrett and K Dhileepan

Project summary

This is a continuation of studies initiated in 2012–2013 to gain a better understanding of the ecology and field efficacy of biocontrol of *Parthenium hysterophorus*—a weed of national significance. Since the mid 1980s, nine insect species and two rust fungi have been introduced, but the field establishment and efficacy status of a large number of these introduced agents are not known in south-eastern Queensland. Also, there is a lack of quantitative knowledge of the entire life-history stages of the weed, including the linkages between its above and below ground growth dynamics.

Trials have been initiated in two sites (Kilcoy and Helidon Spa) in south-eastern Queensland. In each site, 16 permanent 4 m x 4 m plots with varying parthenium infestations (high, medium and low infestations) have been established and the demography of parthenium weed (seedling establishment, growth, survival and fecundity) has been monitored at monthly intervals as a pre-treatment baseline. Soils have been collected from all permanent plots from both sites, at the beginning and at the end of parthenium growing season, for seed-bank estimation and nutrient and microbial estimation in relation to parthenium infestation levels (e.g. high, medium, low and no parthenium infestation levels).

In each site, half of the permanent plots (n=8) will be sprayed with systemic and contact insecticides and fungicides at monthly intervals to maintain parthenium plants free of biocontrol agents (control plots). The remaining plots (n=8) will receive water-spray (treatment plots) where the parthenium plants remain exposed to biocontrol agents prevalent in south-eastern Queensland (e.g. stem-galling *Epiblema* moth, leaf-feeding *Zygogramma* beetle and parthenium winter rust). Within each control and treatment plot, half of the area (2 m x 2 m) will be left ungrazed, while the remaining half (2 m x 2 m) will receive manual grazing (all grass will be clipped manually) at monthly intervals. The demography of parthenium weed populations in both treatment and control plots will be sampled at monthly intervals.

Biocontrol agents not currently present in south-eastern Queensland (e.g. root-feeding *Carmenta* moth and parthenium summer rust) will also be introduced from central and northern Queensland. The seed-feeding *Smicronyx* weevil sourced from central and northern Queensland was released at Helidon Spa.

Collaborators

Prof Steve Adkins (The University of Queensland), Wilmot Senaratne, Dr Raghu Sathyamurthy, Biosecurity Queensland officers, Dr Femi Akinsami, Dr Rob Dehayr, stakeholders (i.e. land owners and farmers)

Key publications

Shabbir A, Dhileepan K, O'Donnell C & Adkins SW 2013, Complementing biological control with plant suppression: implications for improved management of the invasive weed *Parthenium hysterophorus* L, *Biological Control* 64: 270–275.

Dhileepan K. 2012, Reproductive variation in the naturally occurring populations of the weed *Parthenium hysterophorus* in Australia, *Weed Science* 60: 571–576.

Dhileepan K. 2001, Effectiveness of introduced biocontrol insects on the weed *Parthenium hysterophorus* (Asteraceae) in Australia, *Bulletin of Entomological Research* 91: 167–176.

15. Evaluation of restoration effort in riparian landscapes infested with cat's claw creeper vine

Project dates

July 2013 – June 2014

Project team

Olusegun Osunkoya and Christine Perrett

Project summary

Cat's claw creeper vine, a recently declared weed of national significance, is a structural parasite with conspicuous environmental damage. It is common along riparian corridors and inland conserved vegetation (e.g. eucalyptus forests of eastern Australia). Currently there are no proven methods for its control, as regeneration is both from its massive underground tubers and sexually via numerous seeds produced from its long pods.

As part of an evaluation of the impact of herbicide and mechanical/physical control techniques on the long-term reduction of biomass of the weed and expected return of native flora, we have established permanent vegetation plots in:

a. infested and now chemically treated landscapes

b. infested but untreated landscapes

c. un-infested riparian and non-riparian landscapes.

These plots have been used to document changes that occur in seed-bank flora over a 2-year post-treatment period.

Response to treatment varied spatially and temporally. However, following chemical and physical removal treatments, treated patches exhibited lower seed-bank abundance and diversity than infested patches and patches lacking the weed, but differences were not statistically significant. Thus it would be safe to say that spraying herbicides using the recommended rate does not undermine restoration efforts.

Collaborators

Daniel Garcia, Seqwater (stakeholder)

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: 2289–2302.

Osunkoy O, Bayliss D, Panetta D & Vivian-Smith G 2010, Leaf trait coordination in relation to carbon gain and resource use efficiency in invasive and native woody vine species, *Annals of Botany* 106: 371–380.

Perrett C, Osunkoya OO & Clark C 2012, Cat's claw creeper vine, *Macfadyena unguis-cati* (Bignoniaceae) invasion impacts: comparative leaf nutrient content and effects on soil physicochemical properties, *Australian Journal of Botany* 60: 539–548.

16. Cabomba (*Cabomba caroliniana*) ecology

Project dates

October 2010 – July 2015

Project team

Tobias Bickel and Christine Perrett

Project summary

The submersed aquatic weed *Cabomba caroliniana* (cabomba) is widely naturalised in Australia, causing serious environmental and socio-economic impacts. In particular, cabomba has a tendency to create large mono-specific stands and appears to negatively affect native macrophyte diversity. Little is known about cabomba's competitive ability and how it displaces native aquatic plants. This severely hampers control and restoration efforts.

Experiments have shown that cabomba can outgrow potential competitors under suitable conditions (pH 6.5). Within a few weeks, cabomba can attain a 10-fold larger biomass than similar aquatic plants, such as hydrilla. However, competitive superiority over other macrophytes declined with increasing pH.

Contrary to its fast growth in isolation, cabomba seemed to have little direct competitive effects on other macrophytes when grown in co-culture. The growth of both cabomba and native macrophytes appeared to be more affected by their own density rather than direct competitive interactions from other species. However, the fast establishment and growth of cabomba under suitable conditions simply allows cabomba to outgrow potential competitors in the field and subsequently negatively affect them by shading. This explains the dominance of cabomba observed in the field.

Other experiments revealed that cabomba establishment is hampered by a dense cover of other macrophytes, as this interferes with the settlement of fragments on the substrate. The diversity of the recipient plant community had no effect on cabomba establishment. The reduction of cabomba's competitive superiority at higher pH could be exploited for management through manipulation of the water chemistry. Also, conservation of native aquatic plant cover could be a viable management tool to slow down future cabomba spread.

Collaborators

Brisbane City Council, CSIRO, Seqwater, Noosa and District Landcare, Department of Primary Industries Victoria, University of New England, The University of Queensland, Griffith University

Key publications

Bickel TO 2014, A boat hitchhiker's guide to survival: *Cabomba caroliniana* desiccation resistance and survival ability, Hydrobiologia, DOI: 10.1007/s10750-014-1979-1.

17. Impacts of aquatic weeds—mosquito proliferation

Project dates

July 2012 – July 2015

Project team

Tobias Bickel and Christine Perrett

Project summary

There are frequent claims that dense stands of floating and submersed aquatic weeds create breeding grounds for mosquitoes. As there is a range of serious mosquito-borne diseases endemic to Australia (e.g. dengue fever, Ross River fever and Murray Valley encephalitis), aquatic weed infestations could pose a serious health issue. However, there is little scientific evidence linking aquatic weeds with disease vectors.

A pilot study was carried out in 2013–14 to identify the presence of mosquito larvae in dense aquatic weed beds in south-eastern Queensland water bodies and monitor fish densities in these sites. The majority of sampled water bodies showed high densities of fish predators in aquatic weed beds and no mosquito larvae were detected. However, in one site, mosquito larvae were sampled on several occasions in a shallow pond with a very dense water hyacinth infestation. In total, three species of mosquito larvae were sampled (*Culex annulirostris, C. halifaxii* and *Mimoniya elegans*). *Culex annulirostris* is a significant carrier of Ross River virus. Adults of this mosquito species were also observed to use the dense water hyacinth as daytime refuge, presumably as it offers a shady and humid environment.

Results so far suggest that not all aquatic weed infestations pose a threat of mosquito proliferation. The field survey suggests that water hyacinth is the main species of concern as it creates breeding habitats for several mosquito species. Future experiments will investigate the potential to manipulate water hyacinth densities to reduce mosquito breeding.

Collaborators

Brisbane City Council, Gold Coast City Council, Scenic Rim Council, Queensland Health, University of Sydney

18. Targeted research into the control and ecology of *Stevia ovata*

Project dates

July 2012 – June 2015

Project team

Melissa Setter, Stephen Setter and Simon Brooks

Project summary

Stevia ovata (candyleaf) is recorded only in the Ravenshoe area of northern Queensland, where it's observed invasiveness and potential threat to grazing systems has led to its declaration under local laws of the Tablelands Regional Council. A *Stevia ovata* stakeholder group (comprising local government, state government and community members) has requested research into herbicide control of *Stevia ovata,* along with some basic biology studies to help formulate effective management plans.

Trials have therefore been initiated, including:

- determination of germination requirements
- seed persistence in soil and viability in fresh, brackish and saline water
- age to reproductive maturity
- reproductive seasonality
- herbicide screening trials.

Results to date suggest that *Stevia ovata* seed germinates readily at 20 to 30 °C (irrespective of light conditions) and seed persistence appears to be relatively short, with less than 1% of seed viable after 2 years burial. New seedlings can reach reproductive maturity within 3 months, although flowering is relatively synchronised, generally commencing around May. The duration of flowering, however, may vary depending on environmental conditions.

A rate response trial is nearing completion, with several herbicides giving high mortality at one or more of the rates tested. Some chemicals also appear capable of killing seeds located on plants at the time of spraying.

Collaborators

Stevia ovata stakeholder group (includes community members, energy company, local council), Biosecurity Queensland officers, Biosecurity Queensland research (other officers/centres), Far North Queensland Regional Organisation of Councils, Tablelands Regional Council

19. Invasive grass ecology and management

Project dates

July 2006 – June 2015

Project team

Wayne Vogler and Emma Carlos

Project summary

The effect of fire frequency and timing on grader grass populations is the final component of a broader research program, with results from ecology and management studies presented previously.

The research incorporated burning at three times (late dry, early wet and late wet season) and three frequencies (annual, 2-year and 4-year intervals). Changes in pasture species and biomass composition were measured annually. The accidental burning of the entire site in April 2013 resulted in no treatment implementation during 2013–14, with a final biomass assessment completed in May 2014. Despite the loss of the site to fire, the results continue to indicate that dominance of grader grass is maintained by frequent ecosystem disturbance, thus disturbance should be minimised.

Initial herbicide research using both granular and liquid forms of flupropanate has been conducted on Gamba grass, perennial mission grass, thatch grass and grader grass. Results are promising for the control of Gamba and perennial mission grass using a spot application, with little observed movement of the soil-applied flupropanate. Thatch grass proved to be unaffected by flupropanate even at high application rates. The pre-emergent effect of flupropanate on grader grass was significant, although further research is required to refine this as a management tool if it is to be available for land managers. Further trial work on these grasses is planned for 2014–15.

Collaborators

Department of National Parks, Recreation, Sport and Racing, Undara Volcanic National Park, John Clarkson, Biosecurity Queensland officers, Sid Clayton (Mareeba Shire Council)

Key publications

Vogler WD & Green W 2011, Spray topping: a potential tool for managing grader grass (*Themeda quadrivalvis*), in *Proceedings of the 11th Queensland Weed Symposium, Queensland Weed Society* (eds J Hodgon et al.), Brisbane.

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 *Proceedings of the 16th Australian Weeds Conference*, Queensland Weeds Society (eds RD van Klinken, VA Osten, FD Panetta & JC Scanlan), Brisbane, p. 213.

20. Ecology and management of Chromolaena odorata

Project dates

July 2008 – June 2015

Project team

Simon Brooks, Kirsty Gough, Stephen Setter, Shane Campbell and Melissa Setter

Project summary

The project supports the plan to transition from eradication to ongoing management for *Chromolaena odorata* (Siam weed) by providing biological and management information to a range of stakeholders.

Research on the use of low-volume herbicide applications for control of Siam weed was published during 2014. This work identified several effective herbicides that could be used with backpack-style equipment (such as splatter guns) to treat remote, dense patches of Siam weed. The efficiency of this technique was also determined after comparing it with alternate ground-control measures. A further two papers on the effects of fire on Siam weed are being drafted.

A seed burial trial to determine the seed longevity of Siam weed in the dry tropics is continuing. After 4 years, less than 0.3% and 4% of surface-located and buried seed is viable respectively. This is consistent with an earlier trial in the Wet Tropics. Initial studies to provide baseline data on potential water dispersal (immersion, salinity and buoyancy trials) and wind dispersal have also been completed.

Pot trials determining age to maturity have been completed at Charters Towers and South Johnstone, and show that initial flowering behaviour is seasonally driven, as is observed in the field. Young plants established between August and January commenced flowering in early May. Growth, biomass and maturity data are being analysed in conjunction with field data.

Collaborators

Biosecurity Queensland officers (based at South Johnstone, Mareeba and Townsville), Queensland Parks and Wildlife Services

Key publications

Brooks SJ, Gough KL & Campbell SD 2014, Refining low-volume, high-concentration herbicide applications to control *Chromolaena odorata* (L.) King & Robinson (Siam weed) in remote areas, *Plant Protection Quarterly* 29, 71–77.

21. Progress reporting, ecology and control of national weed eradication targets

Project dates

July 2008 – June 2015

Project team

Simon Brooks, Kirsty Gough, Judy Clark, Stephen Setter, Shane Campbell and Melissa Setter

Project summary

The project concentrates on the key biological parameters influencing the field operations targeting tropical weeds for eradication, such as seed-bank persistence, age to maturity, control measures and dispersal potential. The project also develops and refines measures of progress towards eradication.

During 2013–14, a new buried packet field trial investigating *Miconia nervosa* seed persistence was established at a site in the Wet Tropics where similar trials on *Miconia calvescens, Clidemia hirta* and *Mikania micrantha* are in progress. A glasshouse trial of *Limnocharis flava* seed persistence under varying periods of immersion also continued.

Field seed-bank densities and seedling population dynamics of *Clidemia hirta* continue to be monitored within the single known infestation located near Julatten. Immersion, salinity and buoyancy experiments were also completed on seeds of several target species to better understand the potential for these weeds to be spread by water.

Field and laboratory data on the growth to maturity and reproductive seasonality of invasive melastomes continue to be collated to refine guidelines for identifying mature plants and preventing seed production. The first stage of an age-to-maturity pot trial on *M. micrantha* was completed, with some plants growing from seed or cuttings to flowering in 140 days in a quarantine glasshouse.

A foliar herbicide trial on *M. micrantha* has concluded and identified several effective treatments.

Units for reporting eradication progress have been converted from sites to 1 ha management areas, which enables consistent year-to-year reporting of small and large infestations. Considerable advances have also been made in refining reporting data to meet future eradication milestones and developing forward projections for each target species.

Collaborators

Biosecurity Queensland officers (based at South Johnstone and Mossman—provided assistance with field data, locating and accessing trial areas), Four Tropical Weeds Eradication Program, CSIRO Ecosystem Sciences (Atherton)

Key publications

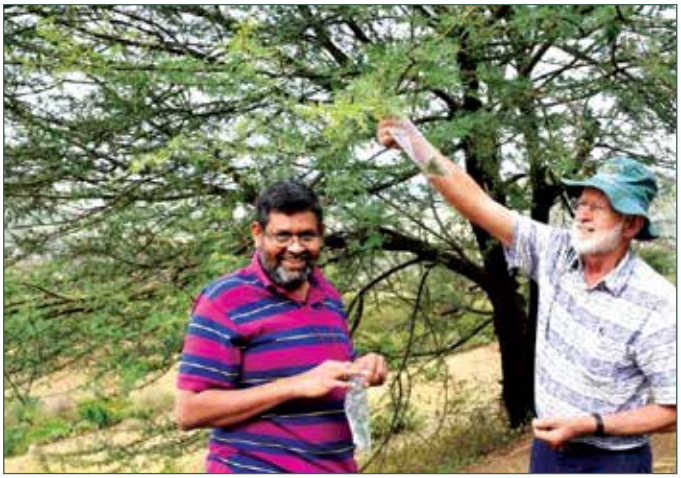
Breaden RC, Brooks SJ & Murphy HT 2012, The biology of Australian weeds 59. *Clidemia hirta* (L.) D. Don., *Plant Protection Quarterly* 27(1): 3–18

Weber JM and Brooks SJ 2013, The biology of Australian weeds 62. *Limnocharis flava* (L.) Buchenau, *Plant Protection Quarterly* 28(4): 101–13

Plot infested with parthenium (*Parthenium hysterophorus*) at a field site near Helidon, Queensland

Galls caused by the *Aceria lantana* budmite on *Lantanae camara* at Mt Coot-tha, Brisbane

Survey for prospective biological control agents for bellyache bush (*Jatropha gossypiifolia*) in Taraporto, Peru



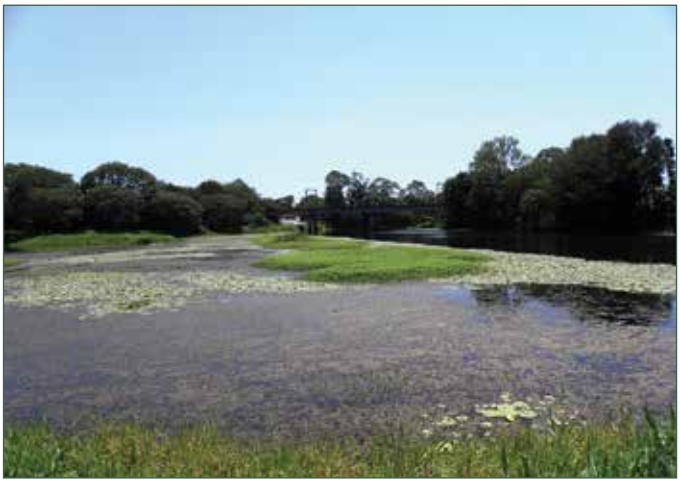
Survey for prospective biological control agents for bellyache bush (*Jatropha gossypiifolia*) in Ethiopia (by K Dhileepan and Stefan Neser)

Cabomba (*Cabomba caroliniana)* flower

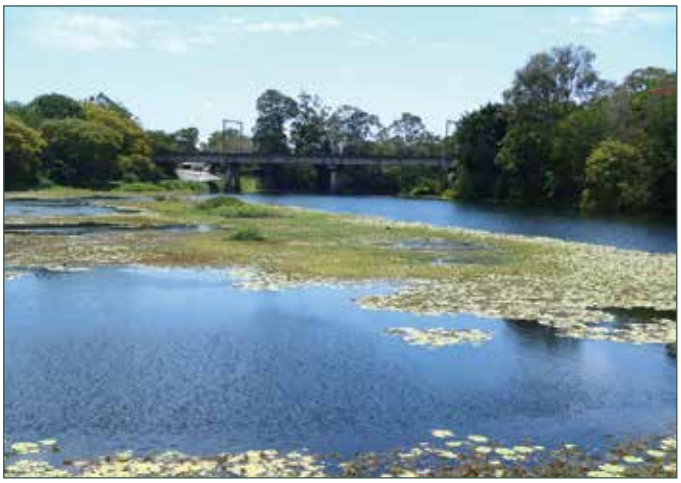
Cabomba (*Cabomba caroliniana*) competing with native aquatic plants in an aquarium experiment

Damage by leaf gall-mite (*Aceria liopeltus*) on prickly acacia (*Vachellia nilotica* subsp. *indica*) in Ethiopia

Acacia gall thrips (*Acaciothrips ebneri*), a new prospective biological control collected on prickly acacia (*Vachellia nilotica* subsp. *indica*) in Ethiopia



Alligator weed before release of flea beetles (*Agasicles hygrophila*) on the Caboolture River, January 2013



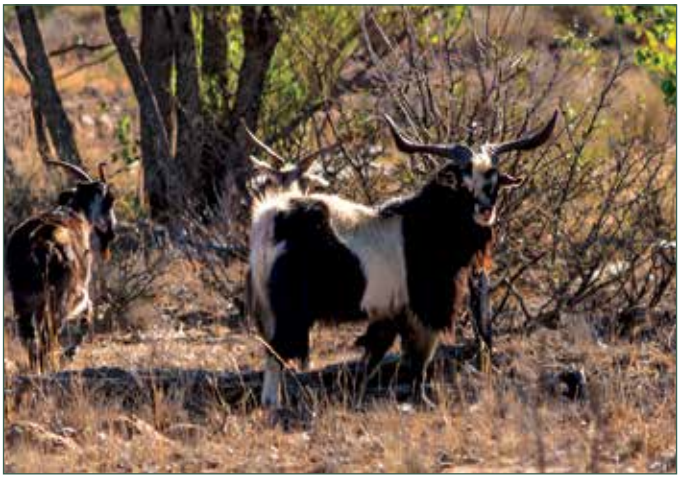
Alligator weed after release of flea beetles (*Agasicles hygrophila*) on the Caboolture River, November 2013

Alligator weed sprayed with picloram during a herbicide trial at the Ecosciences Precinct

Aceria lantanae mites on a lantana (*Lantana camara*) bud

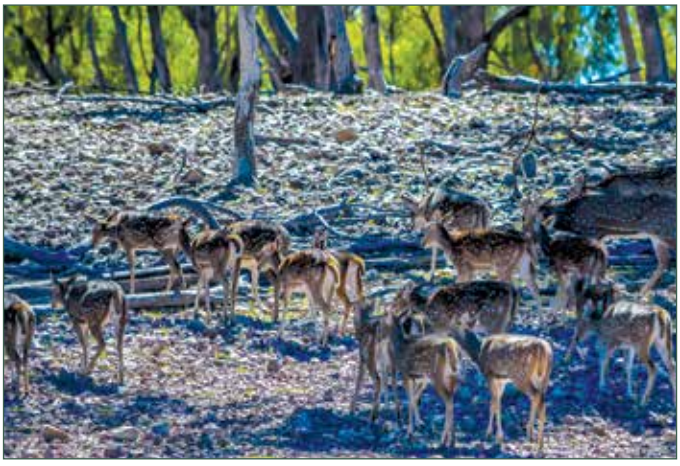
The Morven cluster area will be surrounded by 350 km of additional fencing when construction is completed (2014–15)

Cluster fences are predicted to facilitate more effective management of pasture resources

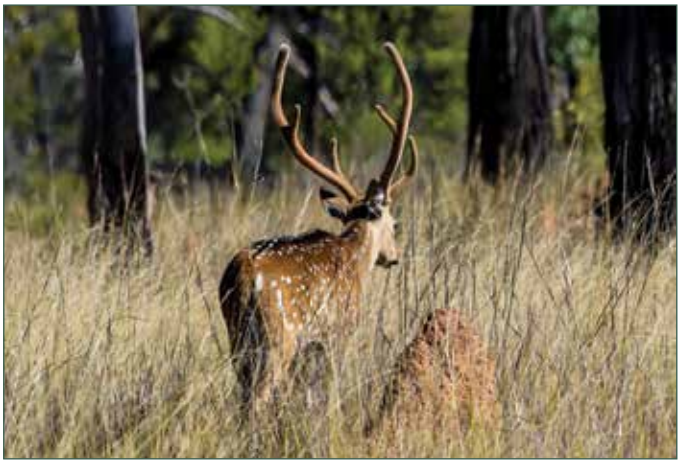


Both feral and managed goats occur within the cluster-fencing area near Morven in south-west Queensland

Wild dog attracted to a canid pest ejector, which can provide target-specific control



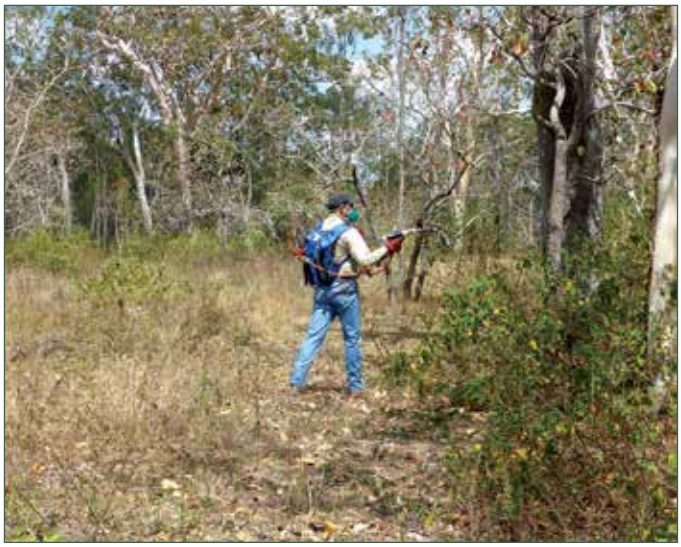
Group of adult female and juvenile chital deer in the Charters Towers region of north Queensland



Mature male chital deer with velvet antlers in the Charters Towers region of north Queensland

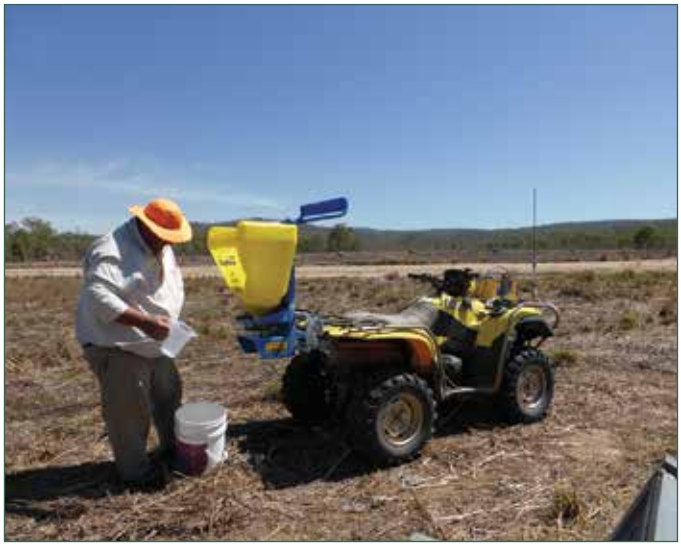
Eueupithecia cisplatensis larva, a biocontrol agent for parkinsonia

Judy Clark monitoring the biocontrol agent *Eueupithecia cisplatensis* at a parkinsonia release site



Demonstrating the use of splatter guns to a ranger group in north Queensland

Stephen Setter collecting bog moss for a herbicide trial



Applying granular flupropanate using a quad bike spreader for Gamba grass control

Applying liquid flupropanate to burnt grader grass for pre-emergent grader grass control

22. Herbicide application research

Project dates

July 2009 – June 2016

Project team

Wayne Vogler, Emma Carlos, Nathan March, Shane Campbell and Christopher Crowley

Project summary

The objective of this project is to improve herbicide control options for priority weeds in central, western and northern parts of the state.

Recently, we have been investigating the use of low-volume/high-concentration applications (splatter method) of herbicides on priority weeds. Bellyache bush can now be effectively treated with metsulfuron-methyl using this technique. Field testing of several herbicides is also currently underway on prickly acacia and rubber vine.

The use of spray misting as a potential control option for prickly acacia regrowth continues to be investigated in the Mitchell grass downs region of western Queensland. Trial work at Barcaldine has shown spray misting has significant potential as an application technique for prickly acacia control. A third round of trial work has been established in the Julia Creek and Winton areas to further prove the concept and compare and refine application rates of fluroxypyr (Starane Advanced®), fluroxypyr and aminopyralid (Hotshot®), and metsulfuron-methyl and aminopyralid (Stinger®). If spray misting proves to be an effective method for applying herbicides to control prickly acacia, approval for its use will be sought from the Australian Pesticides and Veterinary Medicines Authority.

The completion of several years of research on sticky florestina has culminated in the findings being recently published in *The Rangeland Journal*. Based on these data, sticky florestina has now been included on the label of a new product FallowBoss Tordon Herbicide®.

Collaborators

Desert Channels Queensland, Southern Gulf Catchments, landholders (Audreystone Station, Barcaldine; Bodell Station, Julia Creek; Argyle Station, Julia Creek; Bendemere Station, Winton; Ayrshire Downs, Winton), Biosecurity Queensland officers, Northern Gulf Resource Management Group

Key publications

Brazier D, McKenzie J, Owen A, Campbell S, Vitelli J, Reid A & Mayer R 2010, Evaluating herbicides for the control of the invasive weed florestina (*Florestina tripteris* DC. Prod.), in *Proceedings of the 17th Australasian Weeds Conference* (ed. Sue M Zydenbos), The New Zealand Plant Protection Society (Inc) and the Council of Australasian Weed Societies Inc., Christchurch, New Zealand, pp. 421–3.

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

23. Using molecular approaches to detect the presence of invasive species

Project dates

July 2012 – June 2015

Project team

Joseph Vitelli, Jane Oakey and Peter Jones

Project summary

This project aims to develop a methodology for the detection of environmental DNA (eDNA) of invasive species in aquatic systems. The initial test species will be *Mimosa pigra and Annona glabra*—two wetland-associated pest plants. Both are Weeds of National Significance and are currently either the target of eradication (*M. pigra*) or extensive control efforts (*A. glabra*) within Queensland. Using eDNA to detect invasive species in aquatic systems could increase surveillance accuracy, decrease costs of surveys and increase sampling efficiency and therefore sample size, potentially leading to better delimitation and early detection of invasive species in these systems. Overseas, eDNA has been detected successfully for Asian carp and American bullfrogs, and other cryptic or rare aquatic species. DAF has had recent success with invasive mussels and red-eared slider turtles, and are helping develop the technique for tilapia. The project will have a statewide focus and will combine field, glasshouse and laboratory studies. The project will consist of three parts:

1. probe development to amplify, confirm and validate DNA detection
2. an assessment of eDNA release by the target species to determine water sampling strategies (including decay rates)
3. field validation in catchments infested with either M. pigra or A. glabra.

Plant material from target and non-target species was collected for analysis during 2013–14. Laboratory assessments and field validations will be undertaken during 2014–15.

Collaborators

Mackay Reef Catchments, local governments, Biosecurity Queensland officers (including Stacey Harris, Helen Haapakoski, Shane Haack, Mick Jeffrey and Duncan Swan)

Key publications

Vitelli JS, Oakey J, Madigan BA, Driver L, Chamberlain AA & Heard TA 2011, Molecular tools help determine the origins of *Mimosa pigra* infestations in Queensland, Western Australia and the Northern Territory, in *Proceedings of the Eleventh Queensland Weed Symposium. Weed Management; Back to basics*. (ed. J Hodgon), The Weed Society of Queensland, Mackay, pp. 65–68.

24. Research to support the eradication of red witchweed

Project dates

August 2013 – June 2023

Project team

Joseph Vitelli, Natasha Riding, Anna Williams and Annerose Chamberlain

Project summary

Witchweeds (*Striga* spp. other than native species) are declared Class 1 weeds in Queensland, under the *Land Protection (Pests and Stock Route Management) Act 2002*. On 11 July 2013, *Striga asiatica* (red witchweed) was discovered in sugar cane at Habana near Mackay, and has since been gazetted as a notifiable pest in Queensland. Red witchweed is one of the world's worst weeds, as it is an obligate parasite of host plants such as corn (maize), sorghum, rice, sugar cane, cowpeas and other grain crops such as millet and barley. In addition, red witchweed can also parasitise more than 60 other species of grasses. Striga species have been described as 'one of the most serious biological constraints to food production' over large parts of sub-Saharan Africa, where they affect more than 40% of cereal crops and have led to $7 billion in production lost annually to agricultural industries.

The *Red witchweed response plan* identified research as an important component of eradication efforts, and for research to gather and assess scientific literature, international experience and develop research priorities to ensure eradication is supported by sound science. Ten research priorities have been identified to provide information on red witchweed biology and detection methods, and to evaluate control techniques needed to eradicate red witchweed in Queensland.

Collaborators

Landholders (Anthony Abela, Steve and Neiola Vella, Gale and Joe Gretch), Sugar Research Australia (Emilie Fillols, Research Agronomist), Mackay Area Productivity Services, Farleigh Mill Mackay, Biosecurity South Australia, Primary Industries & Regions South Australia (John Virtue, Manager, NRM Biosecurity), BOC Australia (John Roynon, Technical Solutions Engineer; Cassandra Robb, Account Manager, Gas Applications; Chris Dolman, Business Manager)

Key publications

Permit (PER14357) Various products/various crops/witchweeds, expires 31 Aug 2018.

Permit (PER14361) Ethylene/infected premises/witchweeds, expires 31 Mar 2019.

25. Class 1 weed control packages

Project dates

July 2008 – June 2016

Project team

Joseph Vitelli, Annerose Chamberlain and Peter Jones

Project summary

This project aims to develop reliable and effective control strategies that can be integrated into eradication programs for Queensland Class 1 weeds—of which there are currently 53 species naturalised in the state. Research includes investigating control options and collecting basic ecological data (e.g. time to reproductive maturity and soil seed-bank persistence). The project has a statewide focus, bridging both aquatic and terrestrial environments, and combines field, glasshouse and laboratory studies.

To allow for rapid response to any new incursion, a minor use permit is currently being drafted incorporating all Queensland Class 1 species into one permit. The permit should be finalised by 2015.

An accelerated ageing test to determine potential seed longevity is being undertaken on Class 1 weeds where greater than 2500 mature seeds can be sourced. Species targeted to date include Mexican bean tree, Badhara bush, Mexican feather grass, water mimosa, *Acaciella glauca* and Senegal tea.

Alligator weed has been the main species targeted since 2013. Eradication efforts for alligator weed have been hampered by a lack of effective control options (in particular, herbicides targeting its underground storage organs) and is a key knowledge gap identified in the *Weeds of National Significance alligator weed (*Alternanthera philoxeroides *Griseb.) strategic plan 2012–17*. The work at the Ecosciences Precinct is building on past research and evaluating new herbicides, frequency of applications and application rates with the aim to reduce the cost of eradication efforts in Queensland. Studies involve accessing both above and below ground material.

Collaborators

Brisbane City Council, Capricorn Pest Management Group, Logan City Council, Seqwater, Brett Cawthray, (Gladstone Regional Council), Scott Day, Duaringa Rural Lands Officer (Central Highlands Regional Council), Juliet Musgrave Fraser Coast Regional Council, local governments, Tony Dugdale (Victorian Department of Environment and Primary Industries), Biosecurity Queensland officers (including Michael Graham, Lyn Willsher, John Reeve, Lauren O'Bryan, Pedro Hodgson, Stacey Harris, Dan McCudden, Helen Haapakoski, Shane Haack, Mick Jeffrey and Duncan Swan)

Key publications

Silcock RG, Mann MB, Chow S & Vitelli JS 2012, Herbicides to control poisonous *Pimelea* species (Thymelaeaceae), *Crop Protection* 31(1): 99–106.

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

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): 277–286.

26. Improved knowledge of pig population dynamics

Project dates

July 2013 – January 2015

Project team

Matt Gentle, Tony Pople and Joe Scanlan

Project summary

This project investigates the determinants of feral pig population fluctuations (i.e. numerical response). This is important for predicting population fluctuations and modelling the effects of control practices or strategies. Rates of population increase of feral pigs appear to be strongly dependent on survival rates of juveniles. Sows cease to lactate when their crude protein intake drops below critical levels, resulting in high mortality of piglets. Rainfall is an important determinant of plant growth and therefore protein levels. As a result, the potential rate of increase is likely to be a function of food supply driven by rainfall, although the actual rate will also be influenced by other factors. We will use rainfall (from Bureau of Meteorology records) and estimates of pasture growth, pasture biomass and cover (from AussieGRASS and www.longpaddock.qld.gov.au) as key drivers, but other factors that increase mortality (e.g. control campaigns like 1080 baiting, harvesting, predation by wild dogs and availability of prey species) will be investigated where possible. We aim to produce a working population model that could be used to assess likely climate-driven population fluctuations and the impact of control on future population size.

Feral pig densities have been determined from helicopter surveys in 21 kangaroo survey blocks (~2–6000 km^2) across the state and in six survey sites (250–650 km^2) in the Queensland Murray-Darling Basin. Annual harvest commercial offtake has been estimated from feral pig processor and AQIS data for all study areas. The proportion of each area baited per year has been calculated from DAF records, to provide an estimate of the percentage reduction in pig density on each area. The proportion of each area baited for wild dogs has been similarly calculated, to examine the potential effect of wild dog control on feral pig populations.

Collaborators

The Department of the Environment and Heritage Protection and Queensland Murray-Darling Committee have provided data for, or funded, related previous research and have indicated their ongoing support for further analyses of data from this project.

Key publications

Gentle M & Pople A 2013, Effectiveness of commercial harvesting in controlling feral pig populations, Wildlife Research 40 (6), 459–469.

27. Pest animal impact research

Project dates

July 2013 – June 2014

Project team

Matt Gentle and James Speed

Project summary

Feeding and food selection are key ecological processes. Such knowledge can assist by defining the key niche of a species. In pest species applications, knowledge of a pest's diet can help to formulate management strategies through determining the likely prey potentially at risk from predation, or targeting control for periods when prey (or predators) are most at risk or when alternative food abundance is low. Greater understanding of the diet of feral pigs can indicate food availability and hence improve prediction of population dynamics (see previous project summary on pig population dynamics). This project will quantify damage to grain crops from feral pigs, which will be supplemented with dietary information to assess seasonal changes in diet and potential impacts on production and biodiversity. The dietary composition, and overlap between foxes and feral cats will also be explored.

Stomachs from feral pigs, foxes and feral cats were collected opportunistically during lethal control programs or from hunters in the Murray-Darling catchment area of southern Queensland. Dietary composition of 196 feral pig and 280 feral cat/fox stomachs has been completed. Results indicate that cats prey heavily on mice (*Mus musculus*), followed by birds then other mammals. Foxes also preyed upon mice, with invertebrates and carrion also making up a significant proportion of their diet, while these were virtually absent in the diet of cats. Feral pigs are omnivorous, but are heavily reliant upon vegetative matter (>90%). Production crops (particularly sorghum, wheat and cotton) were commonly consumed by pigs (when available). Few animal remains were found in feral pig stomachs suggesting a limited predation impact within grain production environments.

Collaborators

Queensland Murray-Darling Committee

28. Impacts of rabbits on vegetation dynamics in southern Queensland

Project dates

July 2013 – June 2015

Project team

Joe Scanlan, Michael Brennan and Peter Elsworth

Project summary

All grazing has the potential to influence pasture condition. Rabbits can exert considerable pressure on pasture from grazing, comparable to that of domestic livestock. The pasture growth model GRASP now has the capability to simulate changes in pasture condition as a result of changes in pasture utilisation (i.e. the amount of forage consumed as a proportion of amount produced). Thus, utilisation depends on seasonal growing conditions (giving a particular amount of growth) and on the number of grazing domestic, native and feral animals (giving the amount of forage consumed).

Data on pasture standing biomass have been collected from Bulloo Downs (Thargomindah) and Cottonvale (Stanthorpe) for total exclosures, cattle exclosures and grazed areas (open to cattle and rabbits). The GRASP model was fitted to these data sets. A very poor fit for the Thargomindah data was most likely due to imprecise daily rainfall data. The model fitted the data from the Stanthorpe exclosures very well. Lack of detailed information on domestic stock numbers and the relatively small numbers of rabbits will limit our ability to make conclusions on the specific impact of rabbits. The potential economic impacts of changes in pastures will be evaluated using the ENTERPRISE herd dynamics model, economic performance model or the BREEDCOW model.

Collaborators

Mark Ridge (Darling Downs Moreton Rabbit Board), John Thompson (Department of Environment and Heritage Protection)

Key publications

Scanlan J, MacLeod N, & O'Reagain P 2013, Scaling results up from a plot and paddock scale to a property—a case study from a long-term grazing experiment in northern Australia, *The Rangeland Journal* 35: 193–200.

Scanlan JC & Berman D 1999, Determining the impact of the rabbit as a grazing animal in Queensland, in *Proceedings of the VI International Rangeland Congress*, Townsville, pp. 520–521.

29. Rabbits in north Queensland

Project dates

July 2013 – June 2015

Project team

Peter Elsworth, Michael Brennan and Joe Scanlan

Project summary

Rabbits have traditionally occurred in low numbers in northern Queensland—the assumption being that this is due to breeding problems in this warmer part of the state. However, reports of rabbits are increasing. While rabbits are not seen as a major issue by most landholders in northern Queensland, they recognise that rabbits are breeding up and could potentially become a problem in the future. Biosecurity Queensland officers and local government have recognised the potential problem and need better information for the development of management programs. In southern and western parts of Queensland, the biology of rabbits and the corresponding control techniques to manage them are well known. This is not the case in northern Queensland, where temperatures are generally higher than what is considered tolerable for successful breeding by rabbits (Cooke 1977). Rabbits are, however, persisting in this region and so must be successfully breeding. Initial surveys have shown that rabbits are breeding above ground during summer, using hollow logs and bushes as harbour. Further surveys will determine whether breeding occurs year-round and how populations fluctuate seasonally.

Collaborators

Tablelands Regional Council, Mareeba Shire Council, Charters Towers Regional Council

Key publications

Cooke B 1977, Factors limiting the distribution of the wild rabbit in Australia, *Proceedings of the Ecological Society of Australia* 10:113–120.

30. RHD Boost monitoring

Project dates

March 2014 – June 2017

Project team

Peter Elsworth, Michael Brennan and Joe Scanlan

Project summary

Rabbit haemorrhagic disease virus (RHDV) has greatly reduced rabbit numbers throughout Australia. Recent evidence of resistance (Elsworth et al. 2012) and the presence of non-pathogenic rabbit calicivirus (RCV-A1) that provides partial protection against RHDV (Strive et al. 2009; Strive et al. 2013) have led to an exploration for additional strains of RHDV to be imported into Australia for release. This national project (RHD Boost) has completed laboratory testing and identified the best strain for release. To assess its success in the wild and better understand its epidemiology for future releases of RHDV strains, field sites are being established throughout Australia. In Queensland, two sites will be monitored to assess rabbit abundance and disease status prior to and following the release of the RHD Boost strain. This new strain should help further reduce rabbit numbers, but needs to be integrated with conventional control methods.

Collaborators

Invasive Animals Cooperative Research Centre, CSIRO, New South Wales Department of Primary Industries, South Australia Biosecurity, Shane Lampard (Somerset Research Centre), Craig Magnussen, Peter Rouen (Southern Downs Research Centre), Harley West (Landcare), Darling Downs Moreton Rabbit Board

Key publications

Elsworth PG, Kovaliski J, & Cooke BD 2012, Rabbit haemorrhagic disease: are Australian rabbits (*Oryctolagus cuniculus*) evolving resistance to infection with Czech CAPM 351 RHDV? *Epidemiology and Infection* 140: 1972–1981.

Strive T, Wright JD & Robinson AJ 2009, Identification and partial characterisation of a new lagovirus in Australian wild rabbits, *Virology* 384: 97–105.

Strive T, Elsworth PG, Liu J, Wright JD, Kovaliski J & Capucci L 2013, The non-pathogenic Australian rabbit calicivirus RCV-A1 provides temporal and partial cross protection to lethal Rabbit Haemorrhagic Disease Virus infection which is not dependent on antibody titres, *Veterinary Research* 44:51.

Invasive Animals CRC 2014, *RHD-Boost: import and evaluate new rabbit haemorrhagic disease virus (RHDV) variants to strengthen rabbit biocontrol—report to the Vertebrate Pests Committee*, PestSmart Toolkit publication, Invasive Animals Cooperative Research Centre, Canberra, Australia, ‹http://www.feral.org.au/rhd-boost/›.

31. RCV-A1 mapping

Project dates

January 2013 – December 2013

Project team

Peter Elsworth and Michael Brennan

Project summary

It had long been suspected that a benign or non-pathogenic calicivirus was present in Australia's wild rabbit populations and that it may be interfering in the effectiveness of RHDV. In 2009, a non-pathogenic rabbit calicivirus (RCV-A1) was identified and further testing showed that it did provide temporary immunity to RHDV (Strive et al. 2013). RCV-A1 has since been found in cool, wet regions of south-eastern Australia. Analysis of historical samples has also shown it was present in Queensland at Inglewood and Mundubbera in 1996, and Stanthorpe in 2007. As RHDV is still one of the most effective management tools to reduce rabbit numbers, it is important to know if RCV-A1 is present in a population before undertaking control. Samples were collected from seven regions in south-eastern Queensland and one population in northern Queensland. Only two populations had RCV-A1 present—Stanthorpe (10/10 positive) and Highfields (1/14 positive). This shows that RCV-A1 is not widespread in Queensland, being mainly confined to the border regions, but it can be very prevalent in those populations. RHDV may not be as effective in these populations and so other control methods will be even more important.

Collaborators

Tanja Strive (CSIRO), Will Dobbie, Nathan Ring (DDMRB), Tony Hopkins (Feral Animal Control Service), Shane Lampard (Somerset RC), John Pieters (North Burnett RC), Bill Lindsey (Western Downs RC)

Key publications

Strive T, Elsworth P, Liu J, Wright JD, Kovaliski J & Capucci L 2013, The non-pathogenic Australian rabbit calicivirus RCV-A1 provides temporal and partial cross protection to lethal Rabbit Haemorrhagic Disease Virus infection which is not dependent on antibody titres, *Veterinary Research* 44: 51, doi: 10.1186/1297-9716-44-51.

Elsworth PG, Kovaliski J & Cooke BD 2012, Rabbit haemorrhagic disease: are Australian rabbits (*Oryctolagus cuniculus*) evolving resistance to infection with Czech CAPM 351 RHDV? *Epidemiology and Infection* 140 (11), 1972–1981.

Elsworth PG 2011, *Development of genetic resistance to rabbit haemorrhagic disease in wild rabbits* Oryctolagus cuniculus, PhD Thesis, University of Canberra.

32. Assessing impact of rabbits on horticulture

Project dates

July 2013 – December 2015

Project team

Peter Elsworth, Michael Brennan and Joe Scanlan

Project summary

The economic cost of rabbits to agricultural industries in Australia is currently estimated at approximately $200 million per year (Gong et al. 2009), and would have been much more significant in the absence of viral biocontrol tools (Cooke 2013). These figures, however, are produced from estimated losses to the beef and wool industries from competition for feed with livestock. Very little is known about the impact that rabbits have on horticultural crops, although it has long been known that they eat them (Rowley 1963), and this industry is not considered in the estimates of economic costs that rabbits cause to Australia. Queensland produces one-third of the nation's fruit and vegetable produce, which is worth more than $2 billion per year (figures from Growcom). Many of the growing areas are in regions of high rabbit numbers or regions of potential rabbit expansion. Using controlled experiments, the damage of rabbits to certain horticultural crops will be determined. This will enable land users to make better management decisions in regards to control of rabbits. An initial trial of the effect of rabbits on lettuce and broccoli seedlings has commenced.

Collaborators

University of Queensland (Gatton), Growcom, Somerset Research Centre, Southern Downs Research Centre, Landcare, Darling Downs Moreton Rabbit Board, Invasive Animals CRC

Key publications

Cooke B, Chudleigh P, Simpson S & Saunders G 2013, The economic benefits of the biological control of rabbits in Australia, 1950–2011, *Australian Economic History Review* 53: 91–107.

Rowley, I 1963, Bait materials for poisoning rabbits. I. Studies on the acceptance of bait materials by caged rabbits, *Wildlife Research* 8: 56–61.

33. Rabbit population viability in southern Queensland and the influence of above-ground harbour

Project dates

July 2013 – June 2015

Project team

Joe Scanlan, Michael Brennan and Peter Elsworth

Project summary

Data from the Stanthorpe region indicate that the mortality rate of rabbits that live in above-ground harbour is much higher than for rabbits that live in warrens. This raises the question as to whether these rabbits can sustain a population if their only harbour is above ground. An individual-based model of rabbits in the region has been developed using the NetLogo software. The model allows comparison of the effects of different habitat suitability (specifically the amount of harbour) on the population dynamics.

Initial simulations indicate that the removal of harbour will lead to eventual elimination of rabbits, except under very good growing conditions when reproduction rates are very high. Assumptions about the dynamics of predators will have a major effect on population viability. The model will allow us to determine under what conditions (seasonal, predator levels and harbour availability) rabbit populations will remain viable.

Collaborators

David Berman (Queensland Murray-Darling Committee)

34. Movements and distribution of chital deer in north Queensland

Project dates

July 2013 – December 2014

Project team

Tony Pople and Michael Brennan

Project summary

Discussions with landholders in the Charters Towers area have identified the broad distribution of chital deer in the region and an increase in abundance and spread since the 1980s. Deer are now seen as a pest by many landholders, who are controlling deer by ground shooting and seeking alternative control options. This recent increase and spread is surprising, as a population was established in the late 1800s. Limited availability of water and suitable habitat, and predation by wild dogs are possible factors restricting their spread. Information on ranging behaviour (particularly habitat use), drinking frequency and ranging area will help to develop management plans for the species. Future work will examine diet, body condition and reproductive output.

In August 2013, five chital deer (two hinds, one mature stag and two young stags) were darted and collared on Spyglass Research Station. approximately 100 km north of Charters Towers. The collars were fitted with GPS data loggers, recording locations every 90 minutes, and VHF (very high frequency) transmitters for location from the ground. Collars automatically released from the animals in February 2014 and were retrieved using VHF receivers.

The two chital hinds had a home range (minimum convex polygon) during the 6-month study period of approximately 800 to 1200 ha. The one mature chital stag had a home range of approximately 1500 ha, while the two young stags ranged over areas of approximately 2000 to 4500 ha. An Honours student is linking these data with aspects of habitat such as soil type, tree cover and distance to water.

Collaborators

Lauren O'Bryan (Biosecurity Queensland officer, Charters Towers), Steven Anderson (Spyglass Research Station), Jonathan Lee (Animal Biosecurity), Neal Finch (Department of Environment and Heritage Protection), Peter Murray, Matt Amos, Glen Harry, Keith Staines, Deborah McDonald (The University of Queensland, Gatton), Sporting Shooters Association, Australian Deer Association

35. Peri-urban wild dog management

Project dates

June 2012 – June 2016

Project team

Matt Gentle, Ben Allen, James Speed and Lee Allen

Project summary

Relatively little is known about the ecology of peri-urban wild dogs,and how best to control their increasing impacts. Management tools used to control wild dogs across rural Australia have limited use in peri-urban areas. Additionally, peri-urban wild dog management is often contentious, given the presence of a variety of stakeholders with conflicting ideologies. This project investigates peri-urban wild dog ecology, impacts and management in order to identify improved management strategies.

A number of wild dogs (32) have been captured and released with satellite tracking collars attached. Some collared dogs have occupied home range areas inclusive of bushland, while others have occupied road edges (the Bruce Highway) almost exclusively. Breeding and pup-rearing has occurred within a few hundred metres of houses and built-up areas.

Analysis of wild dog scats has indicated a relatively high proportion of small to medium-sized mammals (e.g. rats, bandicoots and wallabies) in their diet. Human-derived food (e.g. rubbish) is also consumed, although not in large quantities.

Local government and media reports indicate that wild dogs negatively impact (chase, attack, injure or kill) a range of species in peri-urban areas—mostly stock (calves, sheep, goats and poultry) and pets (dogs, horses, cats and others). Predation on native fauna is less frequently reported. Great concern is shown for human safety through potential attacks or direct threatening behaviour to people, despite few such incidents being reported.

Testing of non-toxic ejectors (~21 000 ejector nights) continues to demonstrate the utility of the technique in peri-urban environs. Ejectors have been highly target-specific for wild dogs and foxes, and have suffered low levels of human interference and activation by domestic dogs.

Collaborators

Invasive Animals CRC, various local governments (including Moreton Bay, Somerset, Logan and Sunshine Coast Regional Councils, and Brisbane and Gold Coast City Councils), New South Wales Department of Primary Industries, The University of Queensland

Key publications

Allen, BL, Goullet, M, Allen, LR, Lisle, A & Leung, LKP 2013, Dingoes at the doorstep: preliminary data on the ecology of dingoes in urban areas, *Landscape and Urban Planning* 119: 131–135.

36. Wild dogs and calf loss—supplementary analysis of CashCow

Project dates

September 2013 – June 2015

Project leader

Lee Allen

Project summary

CashCow was a $3.5 million, Meat and Livestock Australia–funded project (DAF/Northern Territory Department of Primary Industries/The University of Queensland) conducted between 2008 and 2011 on 72 properties across northern Australia to identify the causes of beef cattle reproductive wastage. Based on grazier responses to questions about wild dog problems, CashCow reported a 5% higher calf loss on properties where owners considered wild dogs a problem and who lethally controlled dogs, compared to properties where owners considered wild dogs not to be a problem and undertook no control. A manipulative study (Allen 2014) comparing calf loss with and without 1080 baiting showed 7% greater calf loss associated with baiting and below-average rainfall. This project investigates a 31 property subset of the CashCow data that involved 14 171 cattle over 64 site years. Analysis of these data also found greater losses on properties with 1080 baits and/or those that had a history of 1080 baiting compared to properties that were not baited (median calf loss 11.3% and 7.1% respectively). However, the properties that were 1080-baited annually or semi-annually (i.e. preventative control) had lower calf loss (median 10.7% and 9.2% respectively) than those that were baited once every 2 to 5 years (i.e. reactive control, median 16.8%). No data are available for wild dog numbers on the individual properties. Data from other sources are being sought. These data again suggest that wild dogs can have an economic impact on beef cattle, but baiting can at times be counter-productive.

Collaborators

CashCow (Tamsin Barnes, Geoffry Fordyce, Kieren McCosker and Michael McGowan), co-authors to manuscripts (Ben Allen, Rick Engeman, Mark Goullet, Luke Leung, Allan Lisle and Angela Wardell-Johnson)

Key publications

Allen LR 2014, Wild dog control impacts on calf wastage in extensive beef cattle enterprises, *Animal Production Science* 54, 214–220.

37. Cluster fencing monitoring and evaluation

Project dates

October 2013 – December 2018

Project team

Lee Allen, Peter Elsworth, Joe Scanlan, Tony Pople, and Bill Johnston

Project summary

In 2013, South West Natural Resource Management Ltd contracted groups of graziers to erect experimental 'cluster fences' around multiple grazing properties to better manage livestock predation by wild dogs, grazing pressure by kangaroos and other pest problems. This approach essentially constitutes a return to dog and marsupial-proof fences. Netting fences potentially offer a possible practical solution to the nation's sheep industry's problems of wild dogs and kangaroos. This 5-year project assesses the costs and benefits of cluster fences, involving monitoring vegetation, kangaroo, wild dog and other wildlife trends inside and outside the Morven cluster fence—the first cluster to be established. Together, these data will feed into an economic evaluation of cluster fences. Although the Morven cluster fence had not been fully erected as of July 2014, two activity index surveys and spotlight counts were conducted in 2013–14. Photo points and vegetation monitoring sites were established in May 2014. Only patchy rain fell across the study area during the 2013–14 summer, and seasonal conditions have been generally poor. Despite this, pastures in some areas are in reasonable condition, in part due to destocking. This is especially the case north of the Morven township. Our wildlife surveys suggest kangaroo densities declined by >50% (182 to 79 kangaroos per km^2 outside and 132 to 55 kangaroos per km^2 inside the cluster fence) between November 2013 and April 2014.

Collaborators

South West Natural Resource Management Ltd

Part 3: Research services

38. Chemical registration—providing tools for invasive pest control

Project dates

July 2012 – June 2018

Project team

Joseph Vitelli and David Holdom

Project summary

Biosecurity Queensland holds permits for use of pesticides to control invasive plants and animals. The need for permits has increased as pesticide registrants focus primarily on more profitable crop protection rather than environmental protection, resulting in reduced availability of registered products for controlling invasive species.

Applications to obtain registrations or permits for pesticide use follow a set of guidelines laid down by the Australian Pesticides and Veterinary Medicines Authority (APVMA). More information is required for new (unregistered) pesticides than for registered products. The volume of information required also varies depending on the sensitivity of the situation (e.g. aquatic environments) and the extent to which the proposed new use varies from existing registered or permitted uses.

Through collaborative work with local governments, agribusiness and scientists, this project facilitates the development of chemical registration submissions and the review and evaluation of permits and products for herbicides used by DAF and local government authorities for the control of invasive plants. Timely permit submissions will ensure:

1. key deliverables within the Invasive Plants and Animals Program are met
2. extended delays in acquiring new emergency and minor use permits to control declared pest plants are minimised
3. an effective network is maintained with the APVMA, leading to the seamless renewal and extension of permits.

Collaborators

Local governments, Seqwater, agribusiness (including Sumitomo Chemical, Nufarm Australia, FMC Australasia, Macspred and DowAgroSciences), Department of National Parks, Recreation, Sport and Racing, Department of Transport and Main Roads, Biosecurity Queensland officers (including Sonia Jordan, Steve Csurhes, Corey Bell, Nathan March, Craig Hunter, Mick Jeffery, Michael Graham, Lyn Willsher, John Reeves, Lauren O'Bryan, Pedro Hodgson, Stacey Harris and Duncan Swan)

Key publications

Twenty-four permits issued by APVMA to Biosecurity Queensland during FY2012–14:

Permit (PER11833) Various herbicides/agricultural non-crop areas, commercial & industrial areas, forests, pastures and rights-of-way/Siam, expires 30 Jun 2024.

Permit (PER11463) Various products and chemicals/non-agricultural areas/environmental weeds, expires 30 Jun 2015.

Permit (PER11670) Glyphosate, metsulfuron-methyl and amitrole/aquatic situations/water mimosa and dead and awake, expires 31 Dec 2014.

Permit (PER11920) 2,4-D amine, metsulfuron-methyl, 2,4-D amine + picloram /pasture stock routes, roadsides and non-crop situations/florestina, expires 31 Mar 2015.

Permit (PER10221) Metsulfuron-methyl 600g/kg/non-potable waterways/alligator weed, expires 31 Mar 2018.

Permit (PER11540) Haloxyfop/ponds, drainage areas, waterways, pastures, roads & utility reserves/hymenachne, expires 30 Jun 2015.

Permit (PER11561) Various herbicides/non-agricultural, native vegetation and pasture/kudzu, expires 31 Aug 2014.

Permit (PER12436) Metsulfuron-methyl, triclopyr, imazapyr and picloram/various situations/kahili ginger, white ginger and yellow ginger, expires 31 Oct 2015.

Permit (PER12497) Access, Brush-Off and Arsenal/various situations/calotrope (*Calotropis procera*), expires 31 Dec 2015.

Permit (PER12726) Roundup Biactive (glyphosate)/aquatic situations/Senegal tea plant, expires 30 Jun 2022.

Permit (PER12926) Metsulfuron-methyl/pasture, non-crop and floodplains/*Mimosa pigra*, expires 31 Mar 2017.

Permit (PER12934) Various herbicides/various situations/candy leaf, expires 31 Aug 2014.

Permit (PER13195) 2,4-D amine/pastures/fireweed, expires 31 Mar 2017.

Permit (PER10367) Metsulfuron-methyl/pastures and non-crop situations/*Parthenium*, expires 30 Jun 2018.

Permit (PER10533) Glyphosate/pasture, non-crop situations/ *Macfadyena unguis-cati* (cat's claw creeper), expires 31 Jul 2018.

Permit (PER10540) 2,4-D amine, glyphosate and metsulfuron/ pasture and fallow (floodplains)/*Lippia*, expires 31 Jul 2018.

Permit (PER13812) Grazon and Access/pastures, rights of way, commercial and industrial areas/coral cactus, expires 30 Nov 2017.

Permit (PER13707) Metsulfuron-methyl/native pastures, rights of way, commercial and industrial areas/bellyache bush, expires 30 Jun 2017.

Permit (PER10397) 2,4-D/pastures and non-crop situations/ *Bryophyllum pinnatum*, expires 30 Jun 2018.

Permit (PER13684) Triclopyr, picloram (Access Herbicide and Tordon DSH)/fluroxypyr (Starane 200 Herbicide)/glyphosate (Roundup Biactive) and imazapyr (Unimaz 250 SL Herbicide)/ various situations/pond apple, expires 30 Jun 2015.

Permit (PER10892) Glyphosate/aquatic areas in Queensland/ *Salvinia molesta*, expires 31 Aug 2016.

Permit (PER10557) Nufarm Arsenal Xpress Herbicide/non-crop areas/*Thunbergia*, expires 30 Sep 2018.

Permit (PER13189) Haloxyfop/Rinyirru (Lakefield) National Park (CYPAL)/*Hymenachne*, expires 30 Jun 2015.

Permit (PER13406) Glyphosate/terrestrial and aquatic areas (Qld)/*Hymenachne* spp., expires 30 Jun 2017.

Where other states hold permits for identical situations, APVMA encourages the inclusion of other states on those permits. This process is much faster than applications for a new permit, typically requiring days rather than months.

39. Pest management chemistry

Project dates

Ongoing

Project team

Stephen Were, Patrick Seydel and Alyson Herbert

Project summary

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

These services comprise pesticide advice and 1080 production for pest management in Queensland, and toxicological and ecotoxicological investigations into the use of vertebrate pesticides. The laboratory, as a unit of Chemical Science, utilises laboratory and formulation facilities at the Health and Food Sciences Precinct at Coopers Plains.

Forensic toxicology

Over the year, our laboratory performed over 80 investigations into possible animal poisonings—57 for sodium fluoroacetate, 21 for strychnine and 5 for anticoagulants. Most investigations related to domestic dogs and cats, but there were also a number involving feral cats.

Formulation chemistry

During the year, our formulation facility produced 2175 L of 1080 36 g/L pig bait solution in accordance with upcoming registration of the formulation with the Australian Pesticides and Veterinary Medicines Authority.

Testing of post-preparation sodium fluoroacetate solutions and meat baits continued throughout the year.

External funding

Research and development contracts

Project/research area	Funding body	Funds ($)
Weed biocontrol in the Solomons and Vanuatu	AusAID	68 000
Weed biocontrol in Papua New Guinea	AusAID	62 000
Controlling calotrope in northern Australia	Meat and Livestock Australia	144 000
Biological control of bellyache bush	Meat and Livestock Australia	7 000
Biological control of prickly acacia	Meat and Livestock Australia	113 000
Biological control of Hudson pear	Department of Industry and Investment (New South Wales)	5 000
Biological control of weeds in Melanesia	Australian Centre for International Research	58 000
Biological control of *Lantana camara*	New South Wales LT/LG	5 000
Weed biocontrol taskforce	New South Wales Government	5 000
Peri-urban wild dog control	Invasive Animals Cooperative Research Centre	186 000
Total		**653 000**

Land Protection Fund

Project/research area	Funds ($)
Weed seed dynamics	8 000
Herbicide application research	114 000
Biological control of bellyache bush	59 000
Biological control of prickly acacia	90 000
Biological control of cat's claw creeper	113 000
Biological control of madeira vine	41 000
Biological control of lantana	99 000
Rearing and release of weed biological control agents	136 000
Biocontrol evaluation	180 000
Ecology and control of wet tropics weeds	63 000
Water weed ecology and management research	136 000
Feral deer best practice research	44 000
Wild dog best practice research	110 000
Rabbit best practice research	328 000
Pesticide authorities	82 000
Pest management chemistry and chemical registration	172 000
Total	**1775 000**

Research staff

Ecosciences Precinct

GPO Box 267
Brisbane Qld 4001

Tel: (07) 3255 4518
Fax: (07) 3846 6371

Email: donna.buckley@daf.qld.gov.au

Email for other staff: firstname.lastname@daf.qld.gov.au

Dr Tony Pople	Principal Scientist
Dr Kunjithapatham Dhileepan	Principal Entomologist
Joseph Vitelli	Principal Weed Scientist
Michael Day	Senior Entomologist
Dr Olusegun Osunkoya	Senior Scientist
Dr Tobias Bickel	Aquatic Weed Scientist
David Holdom	Scientist
Di Taylor	Scientist
Anna Williams	Scientist
Annerose Chamberlain	Experimentalist
Peter Jones	Experimentalist
Christine Perrett	Experimentalist
Natasha Riding	Experimentalist
Wilmot Senaratne	Experimentalist
Liz Snow	Experimentalist
Kumaran Nagalingam	Experimentalist
Donna Buckley	Administration Officer
Courtney Solomons	Scientific Assistant
Patrick Rogers	Senior Operations Supervisor
Dr Bill Palmer	Research Fellow

Health and Food Sciences Precinct

PO Box 156
Archerfield Qld 4108

Tel: (07) 3276 6112
Fax: (07) 3216 6565

Email: alyson.herbert@daf.qld.gov.au

Alyson Herbert	Experimentalist

Robert Wicks Pest Animal Research Centre

Toowoomba

PO Box 102
Toowoomba Qld 4350

Email for staff: firstname.lastname@daf.qld.gov.au

Dr Joe Scanlan	Principal Scientist
Dr Matt Gentle	Senior Zoologist
Dr Lee Allen	Senior Zoologist
Ben Allen	Zoologist
Dr Peter Elsworth	Experimentalist
Michael Brennan	Experimentalist
James Speed	Experimentalist
Cameron Wilson	Scientific Assistant
Naomi Walters	Scientific Assistant

Tropical Weeds Research Centre

Charters Towers

PO Box 187
Charters Towers Qld 4820

Tel: (07) 4761 5700
Fax: (07) 4761 5757

Email: debra.haynes@daf.qld.gov.au
Email for other staff: firstname.lastname@daf.qld.gov.au

Dr Shane Campbell	Professional Leader
Dr Wayne Vogler	Senior Weed Scientist
Dr Faiz Bebawi	Senior Weed Scientist (volunteer)
Simon Brooks	Weed Scientist
Dannielle Brazier	Experimentalist
Barbara Madigan	Experimentalist Agronomist (volunteer)
Kelli Pukallus	Experimentalist
Laura Roden	Experimentalist
Debra Haynes	Centre Administration Officer
Sharon Rossow	Administration Officer (volunteer)
Rodney Stevenson	Operations Supervisor
Carl Andersen	Maintenance Officer
Chris Crowley	Scientific Assistant
Kirsty Gough	Scientific Assistant
Judy Clark	Scientific Assistant
Lauren O'Bryan	Weed and Pest Officer
Emma Carlos	Experimentalist

South Johnstone (Centre for Wet Tropics Agriculture)

PO Box 20
South Johnstone Qld 4859

Tel: (07) 4064 1130
Fax: (07) 4064 2249

Email: donna.vanhaaren@daf.qld.gov.au

Email for other staff: firstname.lastname@daf.qld.gov.au

Melissa Setter	Weed Scientist
Stephen Setter	Experimentalist

Publications and presentations

Journal articles

Allen, BL, Allen, LR, Engeman, RM & Leung, LK-P 2013, Intraguild relationships between sympatric predators exposed to lethal control: predator manipulation experiments, *Frontiers in Zoology* 39:10.

Allen, BL, Engeman, RM & Leung, LK-P 2013, The short-term effects of a routine poisoning campaign on the movement behaviour and detectability of a social top-predator, *Environmental Science and Pollution Research* 21(3): 2178–2190.

Allen, BL, Goullet, M, Allen, LR, Lisle, A & Leung, LK-P 2013, Dingoes at the doorstep: preliminary data on the ecology of dingoes in urban areas, *Landscape and Urban Planning* 119: 131–135.

Allen, BL & West, P 2013, The influence of dingoes on sheep distribution in Australia, *Australian Veterinary Journal* 91(7): 261–267.

Allen, BL 2014, The ecological effects of top-carnivores might not be as universal as previously supposed: a comment on Ripple et al. (2014), *Science*, available at ‹http://comments.sciencemag.org/content/10.1126/science.1241484›.

Allen, BL, Allen, LR, Engeman, RM & Leung, LK-P 2014, Reply to the criticism by Johnson et al. (2014) on the report by Allen et al. (2013), *Frontiers in Zoology*, available at ‹http://www.frontiersinzoology.com/content/11/11/17/comments#1982699›.

Bebawi, FF, Campbell, SD & Mayer RJ 2013, Can competition with pasture be used to manipulate bellyache bush (*Jatropha gossypiifolia* L.) population biology, *The Rangeland Journal* 35: 393–401.

Bengsen, AJ, Gentle, MN, Mitchell, JL, Pearson, HE & Saunders, GR 2013, Impacts and management of wild pigs *Sus scrofa* in Australia, *Mammal Review* 44: 135–147.

Boyne, R, Harvey, SP, Dhileepan, K & Scharaschkin, T 2013, Variation in leaf morphology of the invasive cat's claw creeper *Dolichandra unguis-cati (*Bignoniaceae), *Australian Journal of Botany* 61(6): 419–423.

Boyne, R, Osunkoya, OO & Scharaschkin, T 2013, Variation in leaf structure of the invasive Madeira vine (*Anredera cordifolia*, Basellaceae) at different light levels, *Australian Journal of Botany* 61(5): 412–417.

Day, MD, Kawi, A, Tunabuna, A, Fidelis, J, Swamy, B, Ratutuni, J, Saul-Maora, J, Dewhurst, CF & Orapa, W 2012, The distribution and socio-economic impacts of *Mikania micrantha* (Asteraceae) in Papua New Guinea and Fiji and prospects for its biocontrol, *Pakistan Journal of Weed Science Research* 18: 169–179.

Day, MD, Kawi, AP & Ellison, CA 2013, Assessing the potential of the rust fungus *Puccinia spegazzinii* as a classical biological control agent for the invasive weed *Mikania micrantha* in Papua New Guinea, *Biological Control* 67: 253–261.

Dhileepan, K, Balu, A, Senthilkumar, P, Murugesan, M & Shivas, R 2013, Survey and prioritisation of potential biological control agents for prickly acacia (*Acacia nilotica* ssp. *indica*) from southern India, *Biocontrol Science and Technology* 23: 646–664.

Dhileepan, K, Taylor, DBJ, McCarthy, J, King, A & Shabbir, A 2013, Development of cat's claw creeper leaf-tying moth *Hypocosmia pyrochroma* (Lepidoptera: Pyralidae): implications for establishment as biological control agent in Australia and South Africa, *Biological Control* 67: 194–202.

Dhileepan, K, Taylor, D, Treviño, M & Lockett, C 2013, Cat's claw creeper leaf-mining beetle *Hylaeogena jureceki* Obenberger (Coleoptera: Buprestidae), a host specific biological control agent for *Dolichandra unguis-cati (*Bignoniaceae), *Australian Journal of Entomology* 52: 175–181.

Fleming, PJS, Allen, BL & Ballard, G 2013, Cautionary considerations for positive dingo management: a response to the Johnson and Ritchie critique of Fleming et al., *Australian Mammalogy* 35(1): 15–22.

Gentle, M & Cother, E 2014, Biodegradation of 1080: testing soils in south-eastern Australia for sodium fluoroacetate-degrading micro-organisms, *Ecological Management and Restoration* 15: 1–6.

Khan, AN, Raman, A, Dhileepan, K & Hodgkins, DS 2014, Feeding behaviour of *Anomalococcus indicus* (Hemiptera: Lecanodiaspididae) with supplementary biological notes and biological management of the invasive *Vachellia nilotica indica* (Fabales: Mimosoideae) in north-eastern Australia, *Annales de la Société entomologique de France* 49: 476–492.

MacLeod, ND, Scanlan, JC & Brown, JR 2014, Asymmetric ecological and economic responses for rangeland restoration: a case study of tree thickening in Queensland, Australia, *Rangelands* 36: 37–44.

Matthews, A, Ruykys, L, Ellis, B, FitzGibbon, S, Lunney, D, Crowther, MS, Glen, AS, Purcell, B, Moseby, K, Stott, J, Fletcher, D, Wimpenny, C, Allen, BL, Van Bommel, L, Roberts, M, Davies, N, Green, K, Newsome, T, Ballard, G, Fleming, PJS, Dickman, CR, Eberhart, A, Troy, S, McMahon, C & Wiggins, N 2013, The success of GPS collar deployments on mammals in Australia. *Australian Mammalogy* 35(1): 65–83.

McKenzie, J, Brazier, D, Campbell, S, Vitelli, J, Anderson, A & Mayer, R 2014, Foliar herbicide control of sticky florestina (*Florestina tripteris* DC.), *The Rangeland Journal* 36: 259–265.

O'Reagain, P, Scanlan, J, Hunt, L, Cowley, R & Walsh, D 2014, Sustainable grazing management for temporal and spatial variability in north Australian rangelands: a synthesis of the latest evidence and recommendations, *The Rangeland Journal* 36: 223–232.

Pople, A, Scanlan, J, Cremasco, P & Farrell, J 2014, Population dynamics of house mice in Queensland grain-growing areas, *Wildlife Research* 40(8): 661–674.

Scanlan, J, MacLeod N & O'Reagain, P 2013, Scaling results up from a plot and paddock scale to a property—a case study from a long-term grazing experiment in northern Australia, *The Rangeland Journal* 35: 193–200.

Scanlan, J, Kung, N, Selleck, P & Field, H 2014, Survival of Hendra virus in the environment: modelling the effect of temperature, *EcoHealth* 1–10, DOI: 10.1007/s10393-014-0920-4.

Shabbir, A, Dhileepan, K, O'Donnell, C & Adkins, SW 2013, Complementing biological control with plant suppression: implications for improved management of the invasive weed *Parthenium hysterophorus* L., *Biological Control* 64: 270–275.

Shabbir, A, Dhileepan, K, Khan, N & Adkins, SW 2014, Weed-pathogen interactions and elevated CO_2: growth changes in favour of the biological control agent, *Weed Research* 54: 217–222.

Shivas, RG, Balu, A, Singh, S, Ahmed, SI & Dhileepan, K 2013, *Ravenelia acaciae-arabicae* and *Ravenelia evansii* are distinct species on *Acacia nilotica* subsp. *indica*., *Australasian Mycologist* 31: 31–37.

Strive, T, Elsworth, PG, Liu, J, Wright, JD, Kovaliski, J & Capucci, L 2013, The non-pathogenic Australian rabbit calicivirus RCV-A1 provides temporal and partial cross protection to lethal Rabbit Haemorrhagic Disease Virus infection which is not dependent on antibody titres, *Veterinary Research* 44:51.

Taylor, DBJ & Dhileepan, K 2013, Life history of babul scale *Anomalococcus indicus* (Hemiptera: Lecanodiaspididae), a potential biological control agent for prickly acacia in Australia, *Biocontrol Science and Technology* 23: 1373–1386.

Wang, H-H, Kung, N, Grant, W, Scanlan, J & Field, H 2013, Recrudescent infection supports Hendra virus persistence in Australian flying-fox populations, *PLOS ONE* 8: e80430, DOI: 10.1007/s10393-014-0920-4.

Weber, JM & Brooks, SJ 2013, The biology of Australian weeds 62. *Limnocharis flava* (L.) Buchenau, *Plant Protection Quarterly* 28(4): 101–13.

Books and book chapters

Fleming, PJS, Allen, BL, Allen, LR, Ballard, G, Bengsen, AJ, Gentle, MN, McLeod, LJ, Meek, PD & Saunders, GR 2014, Management of wild canids in Australia: free-ranging dogs and red foxes, in *Carnivores in Australia: past, present and future* (eds AS Glen & CR Dickman), pp. 105–149.

Zachariades, C, Strathie, LW, Day, MD & Muniappan, R 2013, *Proceedings of the Eighth International Workshop on Biological Control and Management of* Chromolaena odorata *and other Eupatorieae*, Nairobi, Kenya, ARC-PPRI, Pretoria, pp 169.

Conference and workshop proceedings

Allen, B 2014, How to collect, store and query pest animal data: a tutorial for practitioners, in *Program and Abstracts 16th Australasian Vertebrate Pest Conference* (ed. M Gentle), Biosecurity Queensland, Brisbane, p. 87.

Allen, B & Gentle, M 2014, Improving vertebrate pest management in peri-urban areas through technological and methodological advances, in *Program and Abstracts 16th Australasian Vertebrate Pest Conference* (ed. M Gentle), Biosecurity Queensland, Brisbane, p. 111.

Campbell, S, Heard, T, Galea, V & van Klinken, R 2013, Where do we stand with weeds from a research perspective, in *Proceedings of the Northern Beef Research Update Conference*, North Australia Beef Research Council, Gympie, Australia, pp. 43–48.

Campbell, SD, Roden, L & Crowley, C 2013, Calotrope (*Calotropis procera*): a weed on the move in northern Queensland, in *Proceedings of the 12th Queensland Weed Symposium* (eds M O'Brien, J Vitelli & D Thornby), Weed Society of Queensland, Brisbane, Australia, pp. 11–14.

Day, MD, Bofeng, I & Nabo, I 2013, Biocontrol of *Chromolaena odorata* in Papua New Guinea, in *Proceedings of the Eighth International Workshop on Biological Control and Management of Chromolaena odorata and other Eupatorieae* (eds C Zachariades, LW Strathie, MD Day & R Muniappan), ARC-PPRI, Pretoria, pp. 117–126.

Day, MD, Brito, AA, da Costa Guterres, A, da Costa Alves, AP, Paul, T & Wilson, CG 2013, Biocontrol of *Chromolaena odorata* in Timor Leste, in *Proceedings of the Eighth International Workshop on Biological Control and Management of* Chromolaena odorata *and other Eupatorieae* (eds C Zachariades, LW Strathie, MD Day & R Muniappan), ARC-PPRI, Pretoria, pp. 134–140.

Gentle, M, Allen, B, Speed, J & Allen, L 2014, The impacts and management of peri-urban wild dogs, in *Program and Abstracts 16th Australasian Vertebrate Pest Conference* (ed. M Gentle), Biosecurity Queensland, Brisbane, p. 110.

Harriott, L, Gentle, M, Traub, R, Soares-Magalhaes, R & Cobbold, R 2014, Disease prevalence and public health risks of peri-urban wild dogs, in *Program and Abstracts 16th Australasian Vertebrate Pest Conference* (ed. M Gentle), Biosecurity Queensland, Brisbane, p. 108.

Seier, MK, Ellison, CA, Corta, G, Day, M & Dhileepan, K 2013, How specific is specific enough? Case studies of three rust species under evaluation for weed biological control in Australia, in *Proceedings of the XIII International Symposium on Biological Control of Weed* (eds Y Wu, T Johnson, S Sing, S Raghu, G Wheeler, P Pratt, K Warner, T Centre, J Goolsby & R Reardon), Hawaii, pp. 89–96.

Shabbir, A, Dhileepan, K, O'Donnell & Adkins, SW 2013, Combining biological control with plant competition: implications for improved management of parthenium weed (*Parthenium hysterophorus* L.), *24th Asia-Pacific Weeds Science Society Conference*, Bandung, Indonesia, 22–25 October.

Snow, E & Dhileepan, K 2013, Update of biological control research for cat's claw creeper and Madeira vine, in *Proceedings of the 12th Queensland Weed Symposium* (eds M O'Brien, J Vitelli & D Thorny), The Weed Society of Queensland, Hervey Bay, Queensland, 15–18 July, pp. 68–71.

Speed, J & Gentle, M 2014, The diet of feral cats and foxes in southern Queensland, in *Program and Abstracts 16th Australasian Vertebrate Pest Conference* (ed. M Gentle), Biosecurity Queensland, Brisbane, p. 134.

Thornby, D & Vitelli, JS 2013, Glyphosate resistance in the crystal ball: are noncropping industries in Queensland at risk?, in *Proceedings of the 12th Queensland Weed Symposium. Weeds; Everyone's Business'* (ed. MM Obrien), Hervey Bay, Queensland, The Weed Society of Queensland, pp. 80–83.

Vitelli, JS & Petroeschevsky A 2013, Expanding the list of aquatic herbicides for use in Australia—the conundrum of do we stop, welcome or remain neutral on its expansion?, in *Proceedings of the 12th Queensland Weed Symposium. Weeds; Everyone's Business'* (ed. MM Obrien), Hervey Bay, Queensland, The Weed Society of Queensland, pp. 89–93.

Other (reports/newsletters/factsheets/theses)

Bickel, TO, Day, M & Vitelli J 2014, *Management of the salvinia infestation in the Dogwood Creek Weir in Miles*, recommendations for management of the Salvinia infestation in Miles, p. 2.

Campbell, S 2014, Erasing an invasive weed, *MLA Feedback Magazine*, March edition, pp. 21.

Carmelito, E 2013, *The diet of Australian dingoes*, Honours thesis, School of Agriculture and Food Science, The University of Queensland.

Dhileepan, K 2013, *Biological control of bellyache bush: native range surveys in South America*, final report (B.NBP.0750) submitted to Meat and Livestock Australia, p. 22, November.

Dhileepan, K 2013, *Bellyache bush rust,* Phakopsora arthuriana (*synonym* P. jatrophicola)—*host testing*, interim final report (B.NBP.0661) submitted to Meat and Livestock Australia, p. 33, August.

Elsworth, P 2014, *The presence and prevalence of the non-pathogenic rabbit calicivirus (RCV-A1) in Queensland*, DAF, Toowoomba.

Morin, L, Heard, T, Scott, J, Sheppard, A, Dhileepan, K, Osunkoya, O & van Klinken, R 2013, *Prioritisation of weed species relevant to Australian livestock industries for biological control*, technical report, submitted to Meat and Livestock Australia, published by Meat and Livestock Australia Limited, Locked Bag 991 North Sydney NSW 2059.

Snow, L & Dhileepan, K 2013, Insects in the fight against cat's claw creeper, *Entomology Society of Queensland News Bulletin* 41(8): 134–136, November.

Conference presentations

Bickel, TO & Perrett, C 2014, Competitive performance of *Cabomba caroliniana*, in *19th Australasian Weeds Conference Proceedings 2014*, Tasmania Weed Society. Hobart, September.

Dhileepan, K, Neser, S & De Prins, J 2014, Biological control of bellyache bush (*Jatropha gossypiifolia*): native range surveys in South America, *XIV International Symposium on Biological Control of Weed*, Kruger National Park, South Africa, 02–07 March.

Dhileepan, K,Taylor, DBJ, Lockett, CJ, Balu, A, Seier, M, Murugesan, S & Pollard K 2014, Biological control of bellyache bush (*Acacia nilotica* subsp. *indica*): current research and future prospects, *XIV International Symposium on Biological Control of Weed*, Kruger National Park, South Africa, 02–07 March.

Elsworth, PG, Brennan, M & Scanlan, J 2014, Tropical rabbits: the spread of wild rabbits in North Queensland, *16th Australasian Vertebrate Pest Conference*, Brisbane, May.

Palmer, WA, Snow, EL & Dhileepan, K 2014, Biological control of the environmental weed Madeira vine in Australia, *XIV International Symposium on Biological Control of Weed*, Kruger National Park, South Africa, 02–07 March.

Seier, M, Pollard, K, Cortat, G & Dhileepan, K 2014, Is the rust *Phakipsora arthuriana* sufficiently host-specific to merit consideration as a biocontrol agent for *Jatropha gossypiifolia* in Australia?, *XIV International Symposium on Biological Control of Weed*, Kruger National Park, South Africa, 02–07 March.

Posters

Elsworth, P 2014, The non-pathogenic rabbit calicivirus RCV-A1 in Queensland, *16th Australasian Vertebrate Pest Conference*, Brisbane, 27–29 May.

Taylor, DBJ, Lockett, CJ & Dhileepan, K 2013, Biological control of prickly acacia: current research and future prospects, in *Proceedings of the12th Queensland Weed Symposium* (eds M O'Brien, J Vitelli & D Thorny), The Weed Society of Queensland, Hervey Bay, Queensland, 15–18 July.

Forums and workshops

Allen, BL 2013, *The ecological roles of dingoes*, Far North Queensland Pest Advisory Forum, Mareeba, May.

Allen, BL 2014, *Management of peri-urban wild dogs*, Far North Queensland Pest Animal Forum, Townsville, April.

Brooks, SJ 2013, *Four tropical weeds research update*, National Four Tropical Weeds Eradication Program Management Committee, Cairns, 27 November.

Brooks, SJ 2013, *Low volume herbicide application—splatter method,* Far North Queensland Pest Advisory Forum, Wujal Wujal, 22 August.

Brooks, SJ 2014, *Four tropical weeds research update,* National Four Tropical Weeds Eradication Program Operational Committee, South Johnstone, 08 April.

Brooks, SJ 2014, *Four tropical weeds research update,* National Four Tropical Weeds Eradication Program Management Committee, Cairns, 22 May.

Brooks, SJ 2014, *Siam research update,* Siam Weed Management Group, Townsville, 2 April.

Campbell, SD 2013, *Use of splatter guns for weed control*, Dry Tropics Pest Advisory Forum, Alpha, 09 October.

Campbell, SD 2013, *Calotrope ecology and control*, Douglas Daly Landcare meeting, Douglas Daly Research Station, Northern Territory, 22 August.

Campbell, SD 2013, *Update on control research on calotrope*, Rubber Bush Advisory Committee Meeting, Katherine, Northern Territory, 23 October.

Campbell, SD 2014, *Weed research update*, Dalrymple Landcare committee meeting, Charters Towers, 21 February.

Campbell, SD 2014, *Weed research update,* Dalrymple Landcare committee meeting, Milray Station, Pentland, 09 May.

Day, MD 2014, *Improving weed management in PNG*, National Agricultural Research Institute, Bubia, 05–07 March.

Dhileepan, K 2013, *Biological control of Cats claw creeper*, New South Wales Biocontrol Task Force meeting, Coffs Harbour, New South Wales, 19 November.

Dhileepan, K 2014, *Biological control of prickly acacia and bellyache bush*, War on Western Weeds Project Advisory Group meeting, Ecosciences Precinct, Brisbane, 15 April.

Fleming, PJS, Ballard, G, Allen, BL, 2013, *Predator-prey interaction review and workshop proceedings*, Vertebrate Pest Research Unit, Biosecurity New South Wales, New South Wales Department of Primary Industries, Orange.

Setter, M & Setter Stephen 2013, *Stevia ovata research update*, Tablelands Regional Council Southern Pest Management Advisory Committee meeting and public forum, Atherton, 13 November.

Snow, EL 2014, *Cat's claw creeper biocontrol*, Gold Coast City Council/SEQ Catchments community workshop on cat's claw creeper biological control, 16 February.

Osunkoya, O 2013, *Dry Tropics Pest Advisory Forum*, dry tropics landcare group and Biosecurity Queensland officers, Alpha, Central Queensland, May.

Vitelli, JS 2014, *Training workshops on herbicide use covering safety issues, risk management, residual herbicides, calibration, herbicide application technology and herbicide*

selection, Removing Barriers to Invasive Species Management in Production and Protection Forests in SE Asia (project number 0515), Baluran National Park, East Java, Indonesia, 01–04 July.

Vitelli, JS 2014, *Weed management—herbicide options*, environmental officers training workshop, QTransport and Main Roads, Brisbane, 26 May.

Vogler, W 2013, *Prickly acacia misting research*, Gulf Catchments Pest Taskforce, Richmond, 28 November.

Vogler, W 2013, *Navua sedge research,* Malanda Beef Group meeting, Malanda, 04 August.

Vogler, W 2013, *Grader grass management*, Victoria River District Catchment Association, Delamere Station, Northern Territory, 21 August.

Vogler, W 2013, *Grader grass management*, Douglas Daly Landcare meeting, Douglas Daly

Research Station, Northern Territory, 22 August.

Vogler, W 2013, *Giant rats tail grass management,* Douglas Daly Landcare meeting. Douglas Daly Research Station, Northern Territory, 22 August.

Vogler, W 2013, *Ecology, biology, management*, University of Queensland students visit, TWRC, Charters Towers, 09 July.

Lectures and seminars

Brooks, SJ 2013, *Class 1 weeds; research, eradication and progress*, University of Queensland Gatton students, Charters Towers, 09 July.

Campbell, SD 2013, *Control options for weeds,* University of Queensland students visit, TWRC, Charters Towers, 09 July.

Day, MD 2013, Chromolaena odorata: *a biocontrol update*, Chromolaena meeting, Brisbane, 10 September.

Day, MD 2014, *Biocontrol of weeds,* principal Biosecurity Queensland officer meeting, Brisbane, 22 May.

Dhileepan, K 2013, *Biocontrol of bellyache bush: survey in South America*, Biological Invasion Seminar Series, Ecosciences Precinct, Boggo Road, Dutton Park, 07 August.

Vitelli, J 2013, *Flupropanate use for GRT control and restrictions,* Simon Warner (CEO SEQ Catchments), Bruce Lord (Community Partnership Manager-Upper Brisbane) and Jim Dale (Chairman, SEQ Catchments Members Association), Ecosciences Precinct, 05 November.

Vitelli, J 2014, *Class 1 weed research and minor use permit*s, principal protection officers, Ecosciences Precinct, 22 May.

Vitelli, J 2014, *Aquatic herbicide research involving carfentrazone*, Kerry Webb (Development Manager) from FMC Australasia and Ray Gurney (Northern Regional Manager) Macspred Australia, Ecosciences Precinct, 12 April.

Vitelli, J 2014, *Aquatic herbicide research involving flumioxazin*, Chris van der (Hoven Marketing Manager) and Patrick Press (Qld Regional Manager), Sumitomo Chemical, Ecosciences Precinct, 26 April.

Vitelli, J 2014, *RWW research priorities*, Red Witchweed Technical Reference Group, Canegrowers, Mackay, 05–06 February.

Scientist in School Program

Pukallus, K 2013, *Biological control overview and TWRC projects*, University of Queensland students, TWRC, Charters Towers, 9 July.

Pukallus, K 2013, *Biological control overview and TWRC projects*, Minister Ian Walker, TWRC, Charters Towers. 26 July.

Field days

Brooks, SJ 2014, *Splatter gun demonstration*, NQ Dry Tropics Pest and Weed Day, Bowen, 21 May.

Campbell, SD 2013, *Splatter guns and weed control in general*, Bellyache Bush Splatter Gun Field Day, Charters Towers, 22 March.

Campbell, SD 2013, *Findings from control research on calotrope*, Calotrope Field Day, Nardoo Station, Gulf of Carpentaria, 24 July.

Dhileepan, K 2013, *Biological control of cats claw creeper,* Dumaresq Catchment Invasive Species Field Day, Glenlyon Dam Park, 14 November.

Pukallus, K 2014, *Overview of current biological control programs at TWRC,* NQ Dry Tropics Field Day, Bowen, 21 May.

Snow, EL 2014, *Cat's claw creeper and Madeira vine biological control agent display*, Brookfield Show, 16 May.

Vogler, W 2014, Prickly Acacia Field Day, Desert Channels Queensland, Barcaldine, 23 May.

Vogler, W 2014, WOWW Prickly Acacia Field Day, Department of Agriculture and Fisheries, Julia Creek, 02 April.

Scientist in School Program

Pukallus, K 2014, DAF plant science competition advisor, Millchester State Primary School, Charters Towers, 04 March.

Pukallus, K 2014, science display, Family Fun Day, Millchester State Primary School, Charters Towers, 03 February.

Media (radio/TV)

Campbell, S 2013, *Calotrope research*, Radio National, 17 July.

Elsworth, P 2014, *Researchers focus on north*, Townsville Bulletin, 08 March

Elsworth, P 2014, *Researchers focus on north*, Cairns Sun, w26 March.

Elsworth, P 2014, *Rabbit research heads north*, ABC Townsville, Mackay, Cairns; Sea FM, Zinc FM, 05 March.

Notes

Notes

CS3806 03/15

Queensland
Government