Technical highlights

Invasive plant and animal research 2018–19

Queensland Government

DAF1095 02/20

Cover photo: A pot trial to determine the life history parameters of *M. racemosa*

Contents

Introduction

This document summarises the 2018–19 research program of the Invasive Plants and Animals Research 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
- Pest Animal Research Centre, Toowoomba
- Tropical Weeds Research Centre, Charters Towers
- Tropical Weeds Research Centre, South Johnstone.

We also collaborate with numerous Queensland, interstate and overseas organisations. 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. biocontrol and herbicides), as well as improved knowledge of pest species' biology and assessment of pest impact.

Notable achievements of the research program for 2018–19 are outlined below.

Invasive plant research

- We continue to assess new biological agents for control of prickly acacia, Navua sedge, bellyache bush, mikania, lantana, giant rat's tail grass, mother-of-millions, cat's claw creeper and several cacti (*Cylindropuntia* species). Also, we are undertaking mass-rearing and release of approved biocontrol agents for parkinsonia, lantana, parthenium and *Cylindropuntia* cacti. Overseas collaboration is essential for this work, and host-specificity of potential agents is being assessed in South Africa, Argentina, India and the United Kingdom. After a long delay, the application to release a gall fly against Siam weed has been approved and mass-rearing will now start for releases during 2019–20.
- Projects are supporting state and national eradication programs for numerous weeds, including red witchweed, miconia, mikania and limnocharis. We carry out ecological studies to determine control timing, and develop control methods as well as techniques to monitor eradication progress. Researchers continue work on treatment methods to deplete the seed bank of red witchweed within a relatively short time frame.
- Trials are identifying effective herbicides, application rates and techniques (e.g. splatter gun, weed sniper and spray misting) for control of a number of weeds in Queensland, including fireweed, prickly acacia, chinee apple, night-blooming cereus, stevia, rubber vine, cabomba, sagittaria, bogmoss, glush weed, giant rat's tail grass and gamba grass. Flumioxazin is showing great promise as a herbicide to control aquatic weeds in Queensland—it is effective at low doses, rapidly taken up by plants and quick to break down.
- We are studying the ecology of a number of weeds to assist management. Information gained—such as seed longevity and age at maturity—help to determine the timing and duration of treatment at a site.

Pest animal research

- We are investigating the ecology and management of chital deer in northern Queensland. This includes assessing the use of helicopters when culling and using a range of survey methods to determine distribution and monitor population trends. In peri-urban areas of south-eastern and central Queensland, we are monitoring the effectiveness of ground-shooting and trapping programs. Through national collaboration, we plan to develop management guidelines.
- A new strain of rabbit haemorrhagic disease virus was released in March 2017 and we have monitored subsequent declines in population size at a number of sites. The resulting low pest density provides a strategic opportunity for long-term suppression of abundance, but follow-up conventional control such as warren ripping often does not occur. Recent work has shown that rabbit biological control can have minimal effect if there is no follow-up mechanical control.
- We have devoted considerable effort to assessing the efficacy of broadscale baiting in controlling feral cats. The data are hard won, as catching, collaring and monitoring the survival of sufficient cats through a baiting program has been difficult. However, we have collected data on minimal non-target impacts and a minor-use permit has been endorsed for one conservation area.
- Our initial assessment of the use of fruit and vegetable baits and aerially deployed meat baits to control feral pigs suggests minimal non-target impact. This data is necessary for the Australian Pesticides and Veterinary Medicines Authority (APVMA) to continue its support of these baiting practices in Queensland.
- We continue to monitor the abundance of kangaroos, wild dogs and other wildlife, as well as pasture condition, following the erection of two large cluster fences in south-western Queensland. Data is being collected on individual properties both inside and outside the clusters. With funding from the Centre for Invasive Species Solutions (CISS), we will now be able to examine the production and economic benefits of cluster fencing. Similar work is being undertaken in Western Australia, providing a valuable comparison. This evaluation will help to direct future investment in cluster fences and fine-tune current operations.

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.
- We obtain minor-use permits from the APVMA as required for certain weed species, herbicides, application methods and situations or environments. Eight minor-use permits were obtained in 2018–19.

Funding, collaboration and research priorities

In the 2018–19 financial year, Biosecurity Queensland's Invasive Plants and Animals Research program received funding from a number of sources. Queensland Government base funds provided $2.5 million; contributions from the Land Protection Fund amounted to $2.2 million; and funding under contracts with external partners totalled $1.3 million (see 'External funding', page 29). Notable funding bodies for the latter were the Australian Government, AgriFutures Australia, Meat and Livestock Australia and CISS.

Our research program for 2018–19 was endorsed by the Research Review Committee—a group of senior scientific, operations and policy staff from Biosecurity Queensland plus representatives from our external stakeholders, including local government, AgForce, the Queensland Farmers' Federation and NRM Regions 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.

Further information

For more information, visit the 'Invasive plant and animal research' page at daf.qld.gov.au. To obtain journal articles and scientific reports, email the project leaders (see 'Research staff', pages 30–31). In addition, you can browse our recent scientific publications in the eResearch archive at daf.qld.gov.au (search 'eResearch archive').

Part 1: Invasive plant research

1. Weed seed dynamics

Project dates

August 2007 – June 2022

Project team

Simon Brooks, Dannielle Brazier and Clare Warren

Project summary

There are many weeds for which we know very little about seed ecology, particularly seed longevity. In this project, we investigate the seed longevity of priority weeds by burying seeds enclosed in bags in two different soil types (black clay and river loam), with and without grass cover and at four burial depths (0 cm, 2.5 cm, 10 cm and 20 cm). The weeds include yellow oleander, mesquite, prickly acacia, chinee apple, parthenium, lantana, gamba grass, calotrope, leucaena, yellow bells, neem tree, stevia and sicklepod.

In a trial that monitors seedling emergence, we are quantifying the environmental conditions influencing the field emergence of neem tree, leucaena, prickly acacia, chinee apple and mesquite. Seedling emergence has now been recorded after several rainfall events. Neem tree seeds appear unlikely to persist longer than a single wet season; this is consistent with the results from buried packets of seeds and is encouraging for control programs. In contrast, prickly acacia and leucaena seedlings emerge only after several rainfall events, typical of weeds with long-lived seed banks.

The project team has recently published papers on the seed longevity of gamba grass and stevia. Also, we have commenced experiments that compare the data from buried seed trials with a laboratory test of relative longevity (controlled ageing test). Correlating these results will reduce the time needed to classify weed seeds into broad longevity categories.

Collaborators

- Shane Campbell (The University of Queensland)
- Faiz Bebawi

Key publications

Bebawi, FF, Campbell, SD & Mayer, RJ 2013, 'Persistence of bellyache bush (*Jatropha gossypiifolia* L.) soil seed banks', *The Rangeland Journal,* vol. 34, pp. 429–438.

Bebawi, FF, Campbell, SD, Mayer, RJ, Setter, MJ & Setter, SD 2018, 'Effects of temperature and burial on seed germination and persistence of the restricted invasive *Stevia ovata* in northern Queensland', *Australian Journal of Botany*, vol. 66, pp. 388–397.

Bebawi, FF, Campbell, SD & Mayer, RJ 2016, 'Seed bank persistence and germination of chinee apple (*Ziziphus mauritiana* Lam.)', *The Rangeland Journal*, vol. 38, pp. 17–25.

Long, RL, Panetta, FD, Steadman, KJ, Probert, R, Bekker, RM, Brooks, SJ & Adkins, SW 2008, 'Seed persistence in the field may be predicted by laboratory-controlled ageing', *Weed Science*, vol. 56, pp. 523–528.

2. Best-practice research on Wet Tropics weeds

Project dates

January 2009 – June 2021

Project team

Melissa Setter and Stephen Setter

Project summary

Weeds are a major threat to the economic productivity and environmental integrity of the Wet Tropics. Many economically significant industries (including agriculture, horticulture and fisheries) are affected if Wet Tropics weeds are not managed effectively. Weed encroachment can decrease biodiversity, placing rare and threatened communities and species at risk. Socially, weed invasion can decrease people's enjoyment of the Wet Tropics (e.g. affecting recreational fishing through the debilitation of fish nurseries, reducing the scenic quality of natural areas, and decreasing the diversity of birds). Both the social and environmental considerations also affect the high tourism value of the region.

There is very little information on several key weed species threatening the Wet Tropics bioregion. Our study species include three Weeds of National Significance (pond apple, hymenachne and bellyache bush) and several others declared under state or local government legislation (e.g. Navua sedge, neem tree and leucaena). Our research targets aspects of ecology and control tools that will support on-ground management, such as seed longevity in soil and water, age to reproductive maturity, rate of spread, dispersal mechanisms and control options developed in herbicide trials.

Collaborators

- Biosecurity officers
- Biosecurity Queensland research officers and centres
- Far North Queensland Regional Organisation of Councils
- Terrain NRM
- Cairns Regional Council
- Cassowary Coast Regional Council
- Tablelands Regional Council
- Etheridge Shire Council
- Mareeba Shire Council
- Douglas Shire Council
- Hinchinbrook Shire Council
- Cook Shire Council

Key publications

Vogler, WD, Carlos, EH, Setter, SD, Roden, L & Setter, MJ 2015, 'Halosulfuron-methyl: a selective herbicide option for the control of the invasive *Cyperus aromaticus* (Ridley) Mattf. & Kukenth (Navua sedge)', *Plant Protection Quarterly*, vol. 30, no. 2.

Brooks, SJ & Setter, SD 2012, 'Soil seed bank longevity information for weed eradication target species', *Pakistan Journal of Weed Science Research*, vol. 18.

Setter, SD, Setter, MJ, Patane, K, Logan, P & Sydes, D 2012, 'Pond apple (*Annona glabra* L.)—investigating novel mechanical control options', *Pakistan Journal of Weed Science Research*, vol. 18.

Setter, SD & Patane, KA 2012, 'Dispersal of pond apple (*Annona glabra*) by rodents, agile wallabies and flying foxes', *Pakistan Journal of Weed Science Research*, vol. 18.

Patane, KA & Setter, SD 2009, 'Fruit and seed production of Koster's curse (*Clidemia hirta*) in Australia', *Proceedings of the 10th Queensland weed symposium*, Yeppoon, Queensland.

Campbell, SD, Carter, EA & Setter, MJ 2009, 'Germination of *Hymenachne amplexicaulis* and *H. acutigluma* under contrasting light, temperature and nitrate regimes', *Plant Protection Quarterly*, vol. 24, no. 1.

Patane, KA, Setter, S & Graham, M 2009, 'Effect of foliar herbicides on the germination and viability of Siam weed (*Chromolaena odorata*) seeds located on plants at the time of application', *Plant Protection Quarterly*, vol. 24, no. 4.

Setter, SD & Patane, KA 2009, 'The spread of neem (*Azadirachta indica*) within a tropical riparian system', *Proceedings of the 10th Queensland weed symposium*, Yeppoon, Queensland.

3. Biocontrol of bellyache bush (*Jatropha gossypiifolia*)

Project dates

January 2007 – June 2020

Project team

K Dhileepan and Di Taylor

Project summary

Bellyache bush (*Jatropha gossypiifolia*), a Weed of National Significance, is a serious weed of rangelands and riparian zones in northern Australia. Bellyache bush has been a target for biocontrol since 1997, with limited success to date. Surveys in Mexico, central and northern South America, and the Caribbean resulted in the release in 2003 of the seed-feeding jewel bug (*Agonosoma trilineatum*), which failed to establish. A leaf rust (*Phakopsora arthuriana*), a leaf-miner (*Stomphastis* sp.), a leaf and shoot-tip webber (*Sciota divisella*) and a gall midge (*Prodiplosis longifila*) have been identified as prospective biocontrol agents. Host-specificity testing of the leaf rust has been completed, but investigation of its life cycle is still underway. Future research will focus on the identification and preliminary host-specificity testing of a gall midge from Bolivia and a leaf-feeding midge from Paraguay.

Jatropha rust

Studies to determine the life cycle of the Jatropha rust (*P. arthuriana*) are now the main focus of our work, which aims to confirm whether the rust can complete its development on just bellyache bush, or whether it needs an alternative host. Current experiments aim to determine more suitable and reliable methods of teliospore conditioning to induce germination and the production of basidiospores, since inoculations with this spore stage will be key to solving the rust's life cycle.

Jatropha leaf-miner

The Jatropha leaf-miner (*Stomphastis* sp.) was imported from Peru and a colony was established in quarantine in November 2014. We have completed no-choice host-specificity testing of the Jatropha leaf-miner on 48 test plant species. Adults laid eggs on numerous non-target species, but larval development occurred on only bellyache bush and its congener physic nut (*J. curcas*). In choice oviposition trials, the females laid eggs equally on both bellyache bush and physic nut. Test results provide strong evidence that the leaf-miner is highly host-specific and is suitable for release in Australia, so we applied for its release. However, because of feedback from the Australian Government Department of Agriculture, we are now conducting no-choice tests for an additional test plant species and choice oviposition tests for some of the test plants on which eggs were laid in the previous no-choice tests. We will resubmit the release application when the tests are completed, and will undertake (in quarantine) studies on the potential impact of the leaf-miner.

Jatropha gall midge

A gall midge (*Prodiplosis ?longifila*) induces rosette galls in shoot-tips, emerging leaves, petioles and stems, resulting in shoot-tip dieback on *J. clavuligera* in Bolivia. A morphologically similar midge species (*P.* not *longifila*) occurs on *J. gossypiifolia* in Paraguay, feeding on leaves, but not inducing galls. To resolve the taxonomic status of these two species (which have distinct feeding habits), adults and larvae of the two midges were field-collected in Paraguay and Bolivia in partnership with scientists at the Fundación para el Estudio de Especies Invasivas in Argentina. These were then imported into Australia for morphological and molecular taxonomic studies. Gall midge samples received from Bolivia and Paraguay were submitted to midge taxonomist Dr Peter Kolesik for identification. Molecular studies on the midges from Paraguay and Bolivia are being undertaken by Dr Kumaran Nagalingam from CSIRO. Morphological and molecular studies suggest that the gall midge from Bolivia and leaf-feeding midge from Paraguay are two distinct species, and not the polyphagous pest species *P. longifila*. This is further confirmed by host-specificity tests conducted in Argentina. In no-choice tests, the leaf-feeding midge from Paraguay caused shoot-tip damage and completed its life cycle on bellyache bush only, not on any of the crop plants (alfalfa, tomato, zucchini, cotton, capsicum and potato) known to be hosts for the polyphagous pest species *P. longifila*.

More specimens of adults and larvae of midges from Paraguay and Bolivia will be imported for morphological and molecular taxonomic research. Limited host-specificity tests have been undertaken for the gall midge from Bolivia. Future choice tests will involve field-collected adults from Bolivia with about 10 test plant species in a large walk-in cage.

Collaborators

- Marion Seier and Kate Pollard (CABI, United Kingdom)
- Guillermo Cabrera Walsh, Marina Oleiro and Carolina Mengoni (Fundación para el Estudio de Especies Invasivas, Buenos Aires, Argentina)
- Peter Kolesik (Bionomics, Adelaide)
- Kumaran Nagalingam (CSIRO, Brisbane)

Damage from the leaf-feeding midge on bellyache bush in Paraguay

No-choice host-specificity testing of the bellyache bush leaf-feeding midge in Argentina

Key publications

Dhileepan, K, Neser, S & De Prins, J 2014, 'Biological control of bellyache bush (*Jatropha gossypiifolia*) in Australia: South America as a possible source of natural enemies', *Proceedings of the XIV international symposium on biological control of weeds*, Kruger National Park, South Africa, pp. 5–10.

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

4. Biocontrol of prickly acacia (*Vachellia nilotica* ssp. *indica*)

Project dates

January 2007 – June 2022

Project team

K Dhileepan, Di Taylor and Boyang Shi

Project summary

Prickly acacia is a Weed of National Significance and a target for biocontrol, but there has been limited success to date. Based on the field host range in India, a scale insect (*Anomalococcus indicus*), a green leaf-webber (*Phycita* sp.) and a leaf weevil (*Dereodus denticollis*) were prioritised for host-specificity testing in quarantine. These agents were either not sufficiently host-specific for release in Australia, or proved difficult to rear in quarantine. With no other prospective agents available from India, our search for new biocontrol agents was redirected to Ethiopia and Senegal. A gall thrips (*Acaciothrips ebneri*) and a gall mite (*Aceria* sp. type-3) from Ethiopia and a gall fly (*Notomma mutilum*) from Senegal have been identified as prospective biocontrol agents and host-specificity testing of these agents is in progress.

Scale insect

In no-choice tests in quarantine, females of the scale insect *A. indicus* developed to reproductive maturity on 17 non-target test plant species. However, this may be an artefact of laboratory conditions, as the scale insect is known to be host-specific under field conditions in India. Therefore, choice trials involving these plants began in the Institute of Forest Genetics and Tree Breeding campus in India in 2014 to ascertain the non-target risks of the Australian test plants under natural field conditions. All prickly acacia plants became infested with the scale insect. In contrast, there was no evidence of any scale insect on any of the non-target plants (*Neptunia major, Acacia irrorata, A. cardiophylla, A. decurrens* and *A. filicifolia*). The trial finished in May 2019.

Gall thrips

A colony of the gall thrips (*Acaciothrips ebneri*) sourced from Ethiopia has been established in a high-security quarantine facility at the Ecosciences Precinct in Brisbane. In quarantine, the gall thrips complete a generation in 4–5 weeks and adults live for 2–3 months. Preliminary studies suggest that a single female can produce about 200 progeny in her lifetime. Life-cycle and longevity studies are continuing. So far, we have completed no-choice host-specificity tests for 50 of 55 test plant species and there is no evidence of gall development on any of these non-target species. Some choice tests and life-cycle studies also need to be completed. We will submit a release application after the host testing is completed, hopefully in early 2020.

Gall mite

Prickly acacia gall mites (*Aceria* sp. type-3) were imported from Ethiopia into quarantine at the Agricultural Research Council Plant Protection Research Institute (ARC-PPRI) in Pretoria, South Africa. A colony has been established on potted prickly acacia plants grown from seeds sourced from Australia. Unfortunately, new gall formation has slowed down with the onset of winter. Host-range testing has been delayed while the culture builds up

sufficient numbers to allow galls to be harvested sustainably. If the culture does not show signs of rapid recovery within the next 2 months, the team from ARC-PPRI will travel to Ethiopia to collect a large consignment of galls, which will facilitate their testing of a large number of species.

Gall fly

The first importation of the gall fly (*Notomma mutilum*) to Australia in late October 2017 yielded no adult flies. A second importation was made in April 2018. Flies began emerging 7 weeks after the stems were imported and continued emerging for 4 weeks. A total of 243 adults emerged from the imported stem pieces, and 237 second-generation adults emerged. Only 98 adults emerged in the third generation and unfortunately the number of galls induced by these adults was reduced, so another importation was needed in June 2019 to boost numbers.

Adult flies mate soon after emergence, and live for up to 7 weeks. Evidence of gall formation can be seen 1–2 weeks after plants are exposed to gravid females. Pupation begins 11–12 weeks after plants are exposed to adults and takes 4–5 weeks. Preliminary no-choice host-specificity trials so far have resulted in no gall formation on *Vachellia bidwillii* plants exposed to adult flies.

Collaborators

- A Balu (Institute of Forest Genetics and Tree Breeding, Coimbatore, India)
- Anthony King, Ayanda Nongogo and Charnie Craemer (ARC-PPRI, Pretoria, South Africa)
- Mindaye Teshome (Forestry Research Centre, Addis Ababa, Ethiopia)
- Nathalie Diagne (Senegalese Institute of Agricultural Research, Centre National de Researches Agronomique, Bambey, Senegal)
- Ocholi Edogbanya (Department of Biological Sciences, Kogi State University, Anyigba, Nigeria)
- Sebahat Ozman Sullivan (Ondokuz Mayis University, Turkey)

Key publications

Dhileepan, K, Taylor, DBJ, Lockett, CJ, Balu, A, Seier, M, Murugesan, S, Tanner, RA, Pollard, KM, Kumaran, N & Neser, S 2014, 'Biological control of prickly acacia (*Vachellia nilotica* subsp. *indica*): current research and future prospects', *Proceedings of the XIV international symposium on biological control of weeds*, Kruger National Park, South Africa, pp. 21–30.

Dhileepan, K, 2009, '2. *Acacia nilotica* ssp. *indica*', in R Muniappan, DVP Reddy & A Raman (eds), *Weed biological control with arthropods in the tropics: towards sustainability*, Cambridge University Press, United Kingdom, pp. 17–37.

5. Biocontrol of cat's claw creeper (*Dolichandra unguis-cati*)

Project dates

July 2001 – June 2021

Project team

K Dhileepan and Di Taylor

Project summary

Cat's claw creeper and Madeira vine are Weeds of National Significance in Australia. Biocontrol is the most desirable option for managing both weeds. Biocontrol of cat's claw creeper commenced in 2001, and since then three agents—a leaf-sucking tingid (*Carvalhotingis visenda*), a leaf-tying moth (*Hypocosmia pyrochroma*) and a leaf-mining beetle (*Hedgwigiella jureceki*)—have been released into the field. All three agents have established, but their distribution and abundance vary widely. Our current research focus is on monitoring the establishment and spread of the leaf-tying moth and the leaf-mining beetle.

Because cat's claw creeper is a perennial vine with abundant subterranean tuber reserves, it can only be effectively controlled when multiple agents attack various parts of the plant. Therefore, future research will involve testing plant pathogens like the leaf-spot disease (*Cercosporella dolichandrae*), the leaf rust (*Prospodium macfadyena*) or the gall rust (*Uropyxis rickiana*), and possibly a leafhopper (*Neocrassana undata*).

Leaf-tying moth

The leaf-tying moth (*H. pyrochroma*) was field-released from 2007 to 2011. The larvae feed destructively on leaves, tying them together with silk, leading to the creation of silken tunnels. We monitored all release sites from November 2018 to March 2019 but took more systematic monthly surveys in four regions (Boompa, Lake Moogerah, Coominya and Oxley) from November 2018 to May 2019. We noted the establishment, seasonal incidence and dispersal of the leaf-tying moth at various distances from the release areas. Larval activity was evident from December 2018 to May 2019, highlighting the possibility of overlapping generations in the field. The moth has continued to spread (up to 22 km from the initial release sites), mostly along riparian corridors.

Leaf-mining beetle

The leaf-mining beetle (*H. jureceki*) was field-released from 2012 to 2017. Both the larvae and the adults are very damaging. Larvae mine within the leaves and adults feed on young leaves. We revisited most of the release sites in November–December 2018 and in February–March 2019 to monitor the establishment and spread of the agent. In each site, we spent 10 minutes counting the number of adults and leaf-mines with larvae and pupal discs. The beetle continues to spread from release sites to new areas. Establishment of the beetle (as evident from leaf-mining with larvae, pupal discs and adults congregating on young leaves) was evident in all the release sites and many surrounding non-release sites. We will continue monitoring the establishment, spread and damage levels of the leaf-mining beetle in selected release sites in south-eastern Queensland.

Leafhopper

The leafhopper (*N. undata*), collected on long-pod varieties of cat's claw creeper in Brazil, was imported into the quarantine facility at the Ecosciences Precinct from the quarantine facility in Pretoria, South Africa on two occasions (July and August 2018). On both occasions, a viable colony of the leafhopper could not be established in quarantine. No further work on the leafhopper is planned.

Plant pathogens

A leaf-spot pathogen (*C. dolichandrae*), which causes necrotic spots and premature leaf abscission, and two rust fungi—a gall rust (*U. rickiana*) and a leaf rust (*P. macfadyena*)—have been identified as prospective biocontrol agents for cat's claw creeper in Australia. Research on the leaf-spot pathogen and the gall rust is underway at CABI in the United Kingdom. Seeds of long-pod and short-pod forms of cat's claw creeper (as the host species of the two pathogens), and seeds and potted test plants of two Australian native plant species for host-specificity testing, were exported to CABI. The leaf-spot pathogen, sourced from South Africa, was exported to CABI and the pathogen has been established and maintained, both in vitro and on its host in quarantine. The gall rust was imported from Paraguay into the quarantine facilities at CABI in November 2018. Evaluation of the two pathogens' life cycles has commenced. For the leaf-spot pathogen, an inoculation protocol has been standardised and preliminary host-specificity testing is in progress. The gall rust has been shown to have a slow disease development on its host, and to date infection has been fairly inconsistent. As a result, the inoculation protocol for reliable infection with this pathogen is still under development. The leaf rust could not be collected during two surveys conducted in Brazil, so additional surveys in 2019 are planned to source the pathogen for future evaluation.

Feeding damage from the cat's claw creeper leaf-tying moth at Lake Moogerah, south-eastern Queensland

Photo courtesy of CABI, United Kingdom

Leaf-spot pathogen infection on cat's claw creeper in quarantine at CABI in the United Kingdom

Photo courtesy of CABI, United Kingdom

Collection of gall rust from cat's claw creeper in Paraguay:
(a) a large gall (b) rust infection on the stem and petiole
(c) rust infection on the lower surface of leaf lamina
(d) rust infection on the upper surface of leaf lamina

Collaborators

- Seqwater
- Marion Seier and Kate Pollard (CABI, United Kingdom)
- Kevin Jackson (Gympie, Queensland)
- Anthony King (ARC-PPRI, Pretoria, South Africa)
- Tanya Scharaschkin (Collinsvale, Tasmania)
- Robert Barreto and Adans Colman (Universidade Federal de Viscosa, Brazil)

Key publications

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*, vol. 52, pp. 175–181.

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

6. Biological control of Navua sedge (*Cyperus aromaticus*): feasibility studies

Project dates

July 2017 – June 2022

Project team

K Dhileepan, Segun Osunkoya, Di Taylor and Boyang Shi

Project summary

Navua sedge (*Cyperus aromaticus*), a perennial grass-like sedge, is an extremely aggressive weed affecting the beef, dairy and sugarcane industries in the Queensland Wet Tropics. The sedge is unpalatable and can form dense stands, replacing palatable tropical pasture species.

In grazing areas, current management options are mechanical and chemical—but these are expensive, offer only short-term relief and may not be practical for large areas. Biocontrol of Navua sedge has not been explored to date. In this project, we explore the feasibility of classical biocontrol for Navua sedge by conducting native range surveys to look for specialist, host-specific natural enemies.

Navua sedge is native to equatorial Africa. Our native range surveys will focus initially on equatorial East Africa (Kenya and Tanzania) and West Africa (Nigeria), because of ease of access and local scientific support. If promising agents are found, we will pursue detailed host-specificity tests. Future work will focus on surveys in other countries in West Africa and on Indian Ocean islands, plus host-specificity testing of prospective agents.

Native range survey

We completed surveys at 42 sites across five south-western states in Nigeria, in partnership with research collaborators from the University of Southern Queensland (Professor Roger Shivas, rust and smut specialist), Kogi State University, Anyigba, Nigeria (Ocholi T Edogbanya, botanist) and the Forestry Research Institute of Nigeria, Ibadan (Emmanuel Chukwuma, plant taxonomist). Two pathogens that caused severe damage on Navua sedge were found—a rust fungus that infected leaves and stems, and a smut fungus that infected florets in the flower heads (inflorescences). Both fungi are considered to have potential as biocontrol agents for Navua sedge in Australia. In addition, leaf-spot pathogens and flower-feeding beetles and thrips were observed. Rust and smut fungi were also collected on other species of sedges. Specimens of the rust and the smut fungi, together with seeds and rhizomes of Navua sedge, were collected in Nigeria and exported to CABI in the United Kingdom and Germany for further research. Herbarium specimens of the rust and smut fungi were prepared, along with dried leaf samples of Navua sedge in silica gel, for future importation into Australia as reference specimens for taxonomic and molecular studies.

Prospective biocontrol agents

The smut fungus that attacks flower heads and destroys florets and seeds was identified as a promising biocontrol agent. The smut pathogen collected in Kenya and Tanzania has been shown to represent a new species of *Cintractia* that differs in molecular phylogenetical analysis from other smut fungi found on sedges. This newly discovered smut will be described as a new species. Field host-range and molecular studies suggest that the smut pathogen is likely to be host-specific. Future morphological and molecular studies on the Nigerian specimens of smut fungus will determine whether the smut fungus is the same as that found in East Africa.

Host-specificity testing

We are preparing an application that seeks approval to declare Navua sedge a biocontrol target. CABI in the United Kingdom has agreed to conduct tests under quarantine to determine whether the smut fungus is host-specific. Funds to conduct host-specificity tests for the smut fungus have been secured from AgriFutures Australia and the Australian Government Department of Agriculture. A plant list for host-specificity testing of Navua sedge is being prepared in consultation with Cyperaceae taxonomists in Australia and overseas. We expect that host-specificity testing of the smut fungus will commence in August or September 2019.

Ecological research

Leaf samples of Navua sedge from equatorial Africa (about 98 from Kew Gardens, about 150 from East Africa and 66 from Nigeria) and Australia (10) will be molecularly compared to determine the source of Australian Navua sedge populations. This information will be used to target future native range surveys in countries with genetically similar Navua sedge populations. A CLIMEX model for Navua sedge is also being developed.

Postgraduate student research

1. A masters student at The University of Queensland completed the research project 'Competitive potential of rhodes grass and humidicola grass to manage Navua sedge' (March–November 2018).
2. A masters student at The University of Queensland commenced the research project 'Comparative germination and growth of Navua sedge against rhodes grass and humidicola grass under simulated grazing and no-grazing conditions' (February–October 2019).
3. A doctorate student at Federation University Australia (Ballarat, Victoria) commenced the thesis 'Navua sedge: biology, ecology and management' (2019–2022).

Surveys in Nigeria for Navua sedge biocontrol agents

A smut fungus infecting Navua sedge inflorescence and seeds in Nigeria

Collaborators

- Professor Roger Shivas (University of Southern Queensland)
- Dr Carol Ellison, Dr Marion Seier and Kate Pollard (CABI, United Kingdom)
- Associate Professor Florentine Singarayer and Aakansha Chadha (Federation University Australia, Ballarat)
- Dr Shane Campbell and Professor Steve Adkins (The University of Queensland, Gatton)
- Dr Mutuku Musili and Frederick Munyao Mutie (East African Herbarium, Kenya)
- Dr John Elia Ntandu (National Herbarium of Tanzania)
- Ocholi T Edogbanya (Kogi State University, Anyigba, Nigeria)
- Emmanuel C Chukwuma (Forestry Research Institute of Nigeria, Ibadan)
- Dr Isabel Larridon (Kew Gardens, United Kingdom)
- Dr Julia Kruse (Germany)

Key publications

Vitelli, JS, Madigan, BA & van Haaren, PE 2010, 'Control techniques and management strategies for the problematic Navua sedge (*Cyperus aromaticus*)', *Invasive Plant Science and Management*, vol. 3, pp. 315–326.

7. Biocontrol of parthenium (*Parthenium hysterophorus*)

Project dates

July 2004 – June 2019

Project team

K Dhileepan, Segun Osunkoya, Jason Callander, Boyang Shi and Christine Perrett

Project summary

Parthenium (*Parthenium hysterophorus* L.) is a noxious weed of grazing areas in Queensland and a Weed of National Significance in Australia. Biocontrol of parthenium has been in progress since the mid-1980s. Eleven biocontrol agents (nine insect species and two rust pathogens) have been released against parthenium in Australia. The majority of these agents have become established and have proven effective against the weed in central Queensland.

Parthenium is spreading further south and is emerging as a serious weed in southern Queensland, where parthenium biocontrol agents have not yet spread. We have initiated a program to redistribute these agents from central Queensland to the south and south-east of the state. This has been supported by funding from the Australian Government Department of Agriculture (under the Rural Research and Development for Profit program) and Meat and Livestock Australia. Effective biocontrol agents have also been exported to India and South Africa.

Biocontrol agent collection in central Queensland

We made four trips to central Queensland (September and December 2018, January and May 2019) for collection and redistribution of parthenium biocontrol agents. We collected biocontrol agents at 19 sites (Gracemere, Mount Hay, Wycarbah, Aphis Creek, Lotus Creek, Carfax, Clermont, Morebridge, Gaylong, Gordon Road, Sandhurst Bridge, Wyntoon, May Downs, Old Orion Road, Rolleston, Bauhinia, Consuelo, Moolayember Creek and Hutton Creek). Due to prevailing dry conditions, limited material was available for collection. The main collected agent (about 600 adults) in September and May was the seed-feeding weevil (*Smicronyx lutulentus*). In December 2018 and January 2019, about 500 stems containing larvae of either *Carmenta* moth or *Listronotus* weevil or both were collected for redistribution into southern Queensland.

Biocontrol agent rearing and redistribution in southern Queensland

We cultured the summer rust in the glasshouse at the Ecosciences Precinct until May 2019. Because of prevailing dry conditions in southern Queensland, there was limited opportunity to release the summer rust in the field.

We routinely surveyed Monto and Gayndah for parthenium biocontrol agents across summer (six occasions). We surveyed Mitchell sites twice, Woodford once, Helidon Spa once and Somerset Dam once. Staff from North Burnett Regional Council surveyed Biggenden release sites. Gatton release sites have not yet been surveyed. The root-feeding *Carmenta* moth, a priority biocontrol agent for parthenium, has now been recovered from Monto, Gayndah, Helidon, Woodford and Biggenden. The leaf-feeding *Zygogramma* beetle has been recovered from Somerset and Woodford. The seed-feeding *Smicronyx* weevil has been recovered from Monto, Gayndah, Biggenden, Helidon and Mitchell. The stem-boring *Listronotus* weevil has been recovered from Monto, Biggenden and Mitchell. The stem-galling *Epiblema* moth and the winter rust are present at all sites in southern and south-eastern Queensland. Leaves infected with summer rust were recovered at Biggenden and Monto.

Community engagement

We met with North Burnett Regional Council and Burnett Catchment Care Association to discuss the refurbishment of a greenhouse facility in Monto for growing parthenium and mass-rearing the biocontrol agent *Zygogramma* beetle. Two nursery sites were established (in Monto and Gayndah) to facilitate collection and redistribution of biocontrol agents in the region. Funding was sought by the Burnett Catchment Care Association in March 2019.

An irrigated nursery site was established in Mitchell, in collaboration with Remote Area Planning and Development Board (RAPAD) Employment Services Queensland and the Queensland Murray–Darling Committee. Staff from the Department of Agriculture and Fisheries presented at North Burnett Regional Council's open days at Monto and Gayndah in September 2018 to local landholders, community groups and council staff on rearing biocontrol agents for target weeds including parthenium. Community groups at Mitchell and Monto have expressed interest in establishing a rearing program for parthenium biocontrol agents. Both groups are seeking funding to refurbish greenhouses in their respective regions. Due to the extended dry summer, parthenium populations have remained low in these regions this season.

Biocontrol agent export to other countries

Field-collected *Smicronyx* adults were exported into a quarantine facility at the Indian Council for Agricultural Research National Bureau of Agricultural Insect Resources (ICAR-NBAIR, Bengaluru) for colony establishment and host-specificity tests.

Collaborators

- Steve Adkins (The University of Queensland)
- S Raghu (CSIRO Ecosystem Dynamics)
- Ken Woodall (RAPID Workforce, Mitchell)
- Tom Garrett and Holly Hosie (Queensland Murray–Darling Committee)
- Ross Bigwood and Bruce Lord (Healthy Land and Water)
- Pat Ryan (Junction View Pest Management Group)
- Glen Proctor, Jenny Voigt, Neale Jensen and John Pieters (North Burnett Regional Council)
- Eric Dyke (Bundaberg Regional Council)

Key publications

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

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

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

8. Biocontrol of parkinsonia (*Parkinsonia aculeata*)

Project dates

March 2013 – December 2018

Project team

Kelli Pukallus, Ainsley Kronk, Joshua Nicholls (until August 2018) and Dannielle Brazier

Project summary

This collaborative project with CSIRO, funded by the Rural Research and Development for Profit program and Meat and Livestock Australia, was completed in December 2018. It involved the mass-rearing, release and monitoring of *Eueupithecia cisplatensis* (UU) and *Eueupithecia vollonoides* (UU2) for the biocontrol of parkinsonia (*Parkinsonia aculeata*) within Queensland. UU and UU2 are leaf-feeding geometrid caterpillars from Argentina; they defoliate the leaflets from the plant, which stresses the plant and reduces flower and seed production.

The Tropical Weeds Research Centre commenced releases in early 2013 at sites in nine local government areas within Queensland. Releases commenced in the Northern Territory and Western Australia in late 2016. To date, releases of UU have been made at 113 sites across three jurisdictions and comprised 3270 adults, 509 700 larvae/eggs and 342 458 pupae (13 574 into Western Australia and 10 322 into the Northern Territory). Additionally, 33 650 UU2 pupae were released at 17 sites (3497 into Western Australia). The release sites are in various terrains and climatic conditions (such as coastal and inland areas, open woodlands, gullies and riparian areas) are on private grazing properties, in national parks, in local government land reserves and on mining leases.

Establishment of UU populations has been observed at 75.5% of the North Queensland and 50% of the Central Queensland release sites. Populations have persisted throughout all seasons of the year and continue to spread into parkinsonia infestations away from release sites. To assess the impact of UU larvae on seedling populations, we are conducting a trial under field conditions along the Burdekin River and under glasshouse conditions. This trial is linked to previous laboratory studies showing that a single UU larva can consume up to 118 leaflets (average 53.4) over a 15-day larval stage, which should severely reduce the health of or kill parkinsonia seedlings.

Assessment of the impact of *Eueupithecia cisplatensis* on parkinsonia seedling recruitment post- flood, Burdekin River, February 2019

Assessment of the impact of *Eueupithecia cisplatensis* on parkinsonia seedling recruitment, Burdekin River, June 2019

Collaborators

- Raghu Sathyamurthy, Gio Fichera and Andrew White (CSIRO, Brisbane)
- Burdekin Shire Council
- Isaac Regional Council
- Central Highlands Regional Council
- Charters Towers Regional Council
- Townsville City Council
- Capricorn Catchments Inc.
- Fitzroy Basin Association Inc.
- CHHRUP (Emerald)
- Queensland Department of Agriculture and Fisheries regional staff
- Western Australia Department of Agriculture and Food
- Northern Territory Department of Land Resource Management

9. Biocontrol of *Cylindropuntia* spp.

Project dates

March 2009 – June 2019

Project team

Michael Day, Peter Jones (until January 2019), Tamara Taylor and Melika Missen

Project summary

Cylindropuntia cactus species are native to tropical America. The group includes *C. kleiniae* and *C. leptocaulis* (pencil cactus), both of which are prohibited weeds in Queensland, and *C. fulgida* (coral cactus), *C. imbricata* (devil's rope pear), *C. pallida* (Hudson pear), *C. prolifera* (jumping cholla), *C. spinosior* (snake cactus) and *C. tunicata* (brown-spine Hudson pear), which are restricted weeds in Queensland.

A biotype of the cochineal *Dactylopius tomentosus* was released in Australia in 1925 to control devil's rope pear, but this biotype does not heavily impact other *Cylindropuntia* species.

The *D. tomentosus* 'cholla' biotype, which proved very effective in South Africa, was approved for field-release against coral cactus in December 2015. It has been released widely in Queensland, as well as in New South Wales, South Australia and Western Australia. At two sites in Queensland where coral cactus was intensively monitored, the cactus was controlled by the cochineal in 21 months.

Additional *D. tomentosus* biotypes have now been released against Hudson pear, devil's rope pear, snake cactus and jumping cholla. We are monitoring these sites for establishment and impact of the cochineal. The cochineal established readily on Hudson pear and jumping cholla at several release sites and is affecting field populations of both weeds elsewhere. The cochineal for snake cactus has been very slow to establish and consequently slow to build up into large numbers. We are testing 10 more biotypes against snake cactus to determine if there is a more effective biotype.

We are conducting hybridisation trials between various *D. tomentosus* biotypes that are likely to meet in the field, to determine possible consequences of hybridisation on effectiveness. Trials conducted so far indicate that the different biotypes will hybridise and that progeny are fertile.

C. fulgida at Moama (New South Wales) in February 2017, before *D. tomentosus* was released

C. fulgida at Moama (New South Wales) in November 2018, after *D. tomentosus* was released

Collaborators

- New South Wales Department of Primary Industries
- Rhodes University (South Africa)
- Dr Helmuth Zimmermann (South Africa)
- Local governments in central and western Queensland
- Desert Channels Queensland
- Southern Gulf NRM
- South West NRM
- Condamine Alliance
- New South Wales Weed Biocontrol Taskforce
- Western Local Land Services (New South Wales)
- Castlereagh Macquarie County Council (New South Wales)
- Western Australia Department of Agriculture and Food
- South Australia Department for Environment and Water
- South Australia Department of Primary Industries and Regions
- Adelaide and Mount Lofty Ranges Natural Resources Management Board (South Australia)

Key publications

Holtkamp, RH 2012, '*Cylindropuntia imbricata* (Haw.) F.M. Knuth—rope pear *Cylindropuntia rosea* (DC.) Backeb.—Hudson pear', in M Julien, R McFadyen & JM Cullen (eds), *Biological control of weeds in Australia: 1960 to 2010*, 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*, vol. 99(6), pp. 551–559.

Jones, PK, Holtkamp, RH, Palmer, WA & Day, MD 2015, 'The host range of three biotypes of *Dactylopius tomentosus* (Lamarck) (Hemiptera: Dactylopiidae) and their potential as biological control agents of *Cylindropuntia* spp. (Cactaceae) in Australia', *Biocontrol Science and Technology*, vol. 25, pp. 613–628.

Jones, PK, Holtkamp, RH & Day, MD 2016, 'The host range of four new biotypes of *Dactylopius tomentosus* (Hemiptera: Dactylopiidae) from southern USA and their potential as biological control agents of *Cylindropuntia* spp. (Cactaceae) in Australia: Part II', *Biocontrol Science and Technology*, vol. 26, pp. 1033–1047.

10. Biocontrol of *Chromolaena odorata*

Project dates

July 2011 – June 2019

Project team

Michael Day, Natasha Riding, Kelli Pukallus and Ainsley Kronk

Project summary

Chromolaena odorata was first reported in Queensland in 1994 and is also present in the Australian territory of Cocos Islands. It was the target of a nationally cost-shared eradication program until 2012, but eradication proved unachievable. The weed was approved as a target for biocontrol in 2011, following several reviews of the program. The gall fly *Cecidochares connexa* is deemed host-specific; it has been tested in 7 countries and subsequently released in 12 countries, including Papua New Guinea, Indonesia, Micronesia and Timor Leste, where it is controlling or aiding the control of *C. odorata*.

The fly was imported into quarantine at the Ecosciences Precinct in Brisbane in February 2012. We have tested it against 18 plant species in the tribe Eupatorieae in choice-minus-the-target plant trials. There was some larval development to adult on *Praxelis clematidea*. Further tests showed that development on *P. clematidea* was minimal and populations could not be sustained. Also, field observations in Palau found no gall formation on *P. clematidea*.

In April 2015, we sought approval for release of the gall fly; this was granted in December 2018. The gall fly was again imported into the quarantine facility at the Ecosciences Precinct to pass through one generation before being released from quarantine and reared at the Ecosciences Precinct and the Tropical Weeds Research Centre (in Charters Towers). We expect the first batch of adults to be removed from quarantine in June 2019, and then mass-reared at the Tropical Weeds Research Centre. We have commenced pre-release impact monitoring of *C. odorata* at selected sites (in both the Wet Tropics and the Dry Tropics) in readiness for the gall fly's release.

Collaborators

- National Agriculture Research Institute (Papua New Guinea)
- National Agriculture and Quarantine Inspection Authority (Papua New Guinea)
- Australian Government Department of Agriculture
- Charters Towers Regional Council
- Cassowary Coast Regional Council
- Townsville City Council

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', *Proceedings of the XIII international symposium on biological control of weeds*, Forest Health Technology Enterprise Team, Morgantown, West Virginia, 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', *Proceedings of the eighth international workshop on biological control and management of* Chromolaena odorata *and other Eupatorieae*, ARC-PPRI, Pretoria, pp. 134–140.

Day, M & McFadyen, RC 2012, '*Chromolaena odorata* (L.) King and Robinson—chromolaena', in M Julien, R McFadyen & J Cullen (eds), *Biological control of weeds in Australia: 1960 to 2010*, CSIRO Publishing, Melbourne, pp. 162–169.

Day, MD, Riding, N & Senaratne, KADW 2016, 'The host specificity and climatic suitability of the gall fly *Cecidochares connexa* (Diptera: Tephritidae), a potential biological control agent for *Chromolaena odorata* (Asteraceae) in Australia', *Biocontrol Science and Technology*, vol. 26, pp. 691–706.

11. Biocontrol of mother-of-millions

Project dates

January 2017 – June 2020

Project team

Michael Day, Natasha Riding, Tamara Taylor and Melika Missen

Project summary

Mother-of-millions (*Kalanchoe* spp. = *Bryophyllum* spp.) is native to Madagascar and has become a major weed in Queensland and northern New South Wales. Earlier work found four potential agents in Madagascar and host-specificity was assessed on two species. These attacked closely related plants in several related genera and approvals for their release were not sought.

With funding from the Australian Government and AgriFutures Australia, this four-year project aims to improve available control options for farmers by exploring biocontrol options from Madagascar. Under this proposal, *Osphilia tenuipes* was collected from Madagascar and imported into a quarantine facility in Orange, New South Wales, where additional host-specificity testing is being conducted. In November 2017, a root-feeding beetle (*Bikasha* sp., previously thought to be *Rhembastus* sp.) was imported from Madagascar into quarantine at the Ecosciences Precinct in Brisbane. We have conducted biology studies and commenced host-specificity testing against closely related plants. To date, the adults have fed on all exposed plant species and larvae have completed development on most of the species tested. At this stage, it is unlikely that we will seek permission for the beetle's release.

Collaborators

- AgriFutures Australia
- Australian Government Department of Agriculture
- New South Wales Department of Primary Industries
- University of Antananarivo (Madagascar)
- Local government and NRM groups

Key publications

Palmer, B & Rafter, M 2012, '*Bryophyllum delagoense* (Ecklon & Zeher) Schinz—mother-of-millions', in M Julien, R McFadyen & J Cullen (eds), *Biological control of weeds in Australia: 1960 to 2010*, CSIRO Publishing, Melbourne, pp. 99–107.

Palmer, W & Senaratne, K 2016, 'Assessment of a stenophagous weevil, *Osphilia tenuipes* (Coleoptera: Curculionidae), as a potential biological control agent for weedy *Bryophyllum* spp. (Crassulaceae) in Australia', *Biological Control*, vol. 100, pp. 101–107.

12. Biocontrol of giant rat's tail grass

Project dates

January 2017 – June 2020

Project team

Michael Day and Natasha Riding

Project summary

Giant rat's tail grass is the common name for the species *Sporobolus pyramidalis* and *S. natalensis*, which are major weeds in coastal and subcoastal Queensland and northern New South Wales. Current control efforts for weedy *Sporobolus* grasses centre on chemical, mechanical, plant-competition and pasture-management methods. However, success has not been achieved and weedy *Sporobolus* grasses continue to rapidly spread into new areas. A biocontrol project was implemented in the 1990s but did not result in the release of any biocontrol agents.

With funding from the Australian Government and AgriFutures Australia, this four-year project aims to improve available control options for farmers by exploring options for biocontrol from South Africa. Rhodes University is conducting field surveys and assessing potential biocontrol agents for their suitability. Several stem-boring wasps appear to be damaging to giant rat's tail grass and the wasps show a degree of specificity in the field. Detailed laboratory studies on one of the *Tetramesa* species suggest that the insect is host-specific to giant rat's tail grass. Trials on this species are continuing in South Africa, and its importation into quarantine at the Ecosciences Precinct in Brisbane is planned for 2019–20. All insects collected have been curated and are undergoing formal identification.

Photo courtesy of Guy Sutton, Rhodes University

Host-specificity testing of biocontrol agents for weedy *Sporobolus* grasses, South Africa

A sleeved, no-choice test control with *Tetramesa* sp. 1, as part of host-specificity testing of biocontrol agents for *Sporobolus natalensis*, Rhodes University

Collaborators

- AgriFutures Australia
- Australian Government Department of Agriculture
- New South Wales Department of Primary Industries
- Rhodes University (South Africa)
- Bundaberg Regional Council
- Gladstone Regional Council
- HQPlantations
- Local governments in coastal and subcoastal Queensland

Key publications

Palmer, B 2012, '*Sporobolus* spp.—weedy sporobolus grasses', in M Julien, R McFadyen & J Cullen (eds), *Biological control of weeds in Australia: 1960 to 2010*, CSIRO Publishing, Melbourne, pp. 569–575.

Palmer, WA, Yobo, KS & Witt, AB 2008, 'Prospects for the biological control of the weedy sporobolus grasses in Australia', *Proceedings of the 16th Australian weeds conference*, The Weed Society of Queensland, Brisbane, pp. 18–22.

Witt, ABR & McConnachie, AJ 2004, 'The potential for classical biological control of invasive grass species with special reference to invasive *Sporobolus* spp.(Poaceae) in Australia', *XI international symposium on biological control of weeds*, CSIRO Entomology, Canberra, pp. 198–202.

13. Biocontrol of pasture weeds in Vanuatu

Project dates

1 July 2018 – 30 June 2023

Project team

Michael Day and Tamara Taylor (from June 2019)

Project summary

Landcare Research New Zealand, with funding from the New Zealand Ministry of Foreign Affairs and Trade, have contracted the Queensland Department of Agriculture and Fisheries to collaborate on a new project on biocontrol of pasture weeds in Vanuatu. Part of this project is to find potential biocontrol agents and assess them for release. Agents that prove to be host-specific and damaging can also be used to help control those weeds in Australia.

Biocontrol has not yet been attempted on three of the targeted weeds—*Senna tora* (a restricted weed in Queensland), *Solanum torvum* (a restricted weed in some Queensland local government areas) and *Urena lobata* (a widespread weed in Queensland). However, existing and effective biocontrol agents for *Spathodea campanulata*, *Mimosa diplotricha*, *Dolichandra unguis-cati*, *Parthenium hysterophorus* and *Lantana camara* will be imported into Vanuatu to help control these weeds. Biocontrol agents already in Vanuatu will be redistributed to areas where they are not yet present.

All biocontrol agents tested and released will be made available to other countries in the Pacific, as part of a regional invasive species management program. International collaborative projects such as this allow greater cooperation between countries, minimise the risk of weed species spreading to other countries (including Australia), develop management strategies for those species that do spread to other countries, and create awareness of weeds and their impacts across the region.

Collaborators

- Landcare Research New Zealand Ltd
- New Zealand Ministry of Foreign Affairs and Trade
- Biosecurity Vanuatu
- Vanuatu Department of Environmental Protection and Conservation
- Malaysian Agricultural Research and Development Institute
- CABI, United Kingdom
- South Pacific Regional Environment Programme
- Secretariat of the Pacific Community

Key publications

Day, MD & Bule, S 2016, 'The status of weed biological control in Vanuatu', *Neobiota*, vol. 30, pp. 151–166.

Day, MD & Winston, RL 2016, 'Biological control of weeds in the 22 Pacific island countries and territories: current status and future prospects', *Neobiota*, vol. 30, pp. 167–192.

14. Control and ecology of *Stevia ovata*

Project dates

July 2012 – June 2021

Project team

Melissa Setter, Stephen Setter and Simon Brooks

Project summary

While *Stevia ovata* (candy leaf) is recorded only in the southern Atherton Tableland region of northern Queensland, it is deemed such a threat to the area that it has been declared under local law by the Tablelands Regional Council. It is also included in the weed lists from the Far North Queensland Pest Advisory Forum and the Wet Tropics Management Authority and is category 3 restricted biosecurity matter under the Queensland *Biosecurity Act 2014*.

A working group of stakeholders—including representatives from local governments, Queensland Government, energy companies and landholders—requested research into herbicide control of candy leaf, along with studies to determine its ecology. We have completed research on the weed's germination requirements, age and size at reproductive maturity, seed longevity in soil (in the Wet Tropics and Dry Tropics of northern Queensland) and seed longevity in water. Also, we have identified effective herbicides for both high-volume foliar and low-volume, high-concentration (splatter-gun) application techniques.

In a pre-emergent trial using pots containing seeds of candy leaf, we tested 14 herbicides for pre-emergent activity. From this, we identified several effective pre-emergent herbicides.

These results have been incorporated into local *Stevia ovata* management plans.

Collaborators

- *Stevia ovata* Stakeholder Group (including community members and representatives from industry and government)
- Biosecurity officers
- Biosecurity Queensland research officers and centres
- Far North Queensland Regional Organisation of Councils
- Tablelands Regional Council
- Terrain NRM

Key publications

Bebawi, FF, Campbell, SD, Mayer, RJ, Setter, S & Setter, M 2018, 'Effects of temperature and burial on seed germination and persistence of *Stevia ovata* (Stevia ovata Willd.)', *Australian Journal of Botany*, vol. 66(5), pp. 388–397.

Setter, MJ, Setter, SD, Brooks, SJ & Campbell, SD 2016, '*Stevia ovata*—not so sweet', *Proceedings of the 20th Australasian weeds conference*, Weeds Society of Western Australia, Perth, pp. 13–16.

15. Sicklepod ecology and control

Project dates

January 2016 – June 2021

Project team

Melissa Setter and Stephen Setter

Project summary

Sicklepod (*Senna obtusifolia*) is a serious weed of many parts of northern Queensland (from Cape York to Mackay) and occurs in pastures, crops and corridors such as road and powerline clearings and creek banks. In this project, we aim to improve knowledge about the longevity and production of sicklepod seed, including the seasonality of seed production and environmental triggers for germination (rainfall and temperature) relative to local conditions. We also investigate pre-emergent and low-volume, high-concentration herbicide control options for sicklepod.

Some early experimental results are:

- Seeds are persisting for at least 24 months after burial, but the viability has reduced from 92% initially to 70%, 3.5% and 1% at 0 cm, 2.5 cm and 10 cm burial depths respectively after 24 months.
- In pot trials, seedling emergence and establishment have been effectively suppressed by herbicides containing picloram.

Field trials to further develop pre-emergent herbicide options are planned for 2019–20.

Collaborators

- Biosecurity officers
- Biosecurity Queensland research officers and centres
- Cape York NRM
- Local governments in northern Queensland (e.g. Cook Shire Council)
- Queensland Parks and Wildlife Service
- Landowners and pastoralists
- Herbicide manufacturers

16. Aquatic weeds of northern Australia—ecology and control

Project dates

January 2015 – June 2021

Project team

Melissa Setter and Stephen Setter

Project summary

Aquatic weeds are a burgeoning problem with the increase in commercial trade of aquatic plants, particularly via the internet. Several escaped aquarium plants are particularly problematic in the Wet Tropics, and have potential distributions across large parts of northern Australia. These include hygrophila (*Hygrophila costata*), bogmoss (*Myacca fluviatilis*) and Amazonian frogbit (*Limnobium laevigatum*).

In this project, we address a number of ecological questions to improve management of current infestations and to predict and restrict further infestations. We are also investigating control options. Specifically, we are researching:

- seed and vegetative reproduction abilities in regional populations of hygrophila
- herbicide control of bogmoss
- seed viability and longevity in regional populations of Amazonian frogbit.

Initial results indicate that stem fragments of hygrophila are able to float and survive for 3 weeks in fresh or brackish water and 2 weeks in salt water, demonstrating the potential for dispersal via water movement. Also, regional populations of Amazonian frogbit were found to have viable seed.

Collaborators

- Biosecurity officers
- Far North Queensland Regional Organisation of Councils
- Terrain NRM
- Cairns Regional Council
- Cassowary Coast Regional Council
- Hinchinbrook Shire Council
- Russell Landcare and Catchment Group
- Jaragun Pty Ltd

Key publications

Setter, MJ, Setter, SD & Styman, DT 2017, 'Survival and buoyancy of *Hygrophila costata* stem fragments in salt, brackish and fresh water', *Proceedings of the 14th Queensland weed symposium*, The Weed Society of Queensland, Port Douglas.

Setter, SD, Graham, Michael F, Setter, MJ & Waterhouse, BM 2017, '*Limnobium laevigatum* (Amazonian frogbit) ecology and control in the Wet Tropics', *Proceedings of the 14th Queensland weed symposium*, The Weed Society of Queensland, Port Douglas.

Setter, SD, Patane, KA, Madigan, BA & Setter, MJ 2011, 'Bogmoss (*Mayaca fluviatilis* Aubl.)—investigating control options for this new threat to our waterways', *Proceedings of the 11th Queensland weed symposium*, The Weed Society of Queensland, Mackay.

17. Water weed management research

Project dates

October 2010 – June 2020

Project team

Tobias Bickel, Christine Perrett and Joseph Vitelli

Project summary

Management of aquatic weeds is significantly hampered by a lack of efficient control techniques and the absence of integrated management options. In this project, we investigate several aspects of aquatic plant control with flumioxazin and how to best integrate it with other control options.

We have investigated plant uptake, breakdown and environmental fate of flumioxazin applied to experimental ponds. Flumioxazin was applied as an aqueous solution to the water column in experimental ponds at 50 ppb ai (parts per billion active ingredient) for cabomba and 200 ppb ai for sagittaria. It was rapidly absorbed by the target plants and we detected high concentrations in plant tissue within a very short time (between 15 minutes and 2 hours). We estimated that about 70% of all flumioxazin applied was taken up by the plants.

Flumioxazin applied to the water breaks down rapidly through hydrolysis (pH dependent) and UV radiation. In the conditions tested in the experiments (pH 6.5), flumioxazin was below detection limit (‹0.1 ppb) in 4–8 days. A small amount of flumioxazin was measured in the substrate after 24 hours, but was not detectable after 48 hours. Most likely, flumioxazin does not accumulate in the substrate, but can be present in pore water at low concentrations after application.

Flumioxazin will be an efficient and economic tool for control of established and emergent aquatic weeds in Queensland. Future research will investigate improved application techniques and strategies.

Collaborators

- Junfeng Xu, Nguyen Nguyen and Hitasha Singh (The University of Queensland)
- CSIRO
- Queensland Department of Environment and Science
- Seqwater
- Sumitomo Chemical
- NIWA
- Brisbane City Council
- Noosa and District Landcare
- Victoria Department of Jobs, Precincts and Regions
- New South Wales Department of Primary Industries
- University of Düsseldorf (Germany)
- Griffith University
- Macspred

Key publications

Bickel, TO, Perrett, C, Vitelli, J, Xu, J & Adkins, S 2018 'Control of *Cabomba caroliniana* with flumioxazin: control efficacy and the effect of environmental factors', *15th international symposium of aquatic plants*, Queenstown, New Zealand.

Bickel, TO 2017, 'Processes and factors that affect regeneration and establishment of the invasive aquatic plant *Cabomba caroliniana*', *Hydrobiologia*, vol. 788(1), pp. 157–168.

Bickel, TO 2015, 'A boat hitchhiker's guide to survival: *Cabomba caroliniana* desiccation resistance and survival ability', *Hydrobiologia*, vol. 746, pp. 123–134.

18. Giant rat's tail grass management

Project dates

July 2017 – June 2022

Project team

Wayne Vogler and Clare Warren

Project summary

Giant rat's tail grass is an invasive grass that is widespread predominantly in eastern Queensland but is continuing to spread. It causes significant problems in animal production systems, forestry and the wider environment. In this project, we concentrate on improving use of the herbicide flupropanate, fertiliser and fire in management of the grass, as well as management in seasonally wet areas. The project is being conducted in conjunction with Gladstone Regional Council and Economic Development Queensland in a range of situations including grazing, peri-urban development and forestry.

In small-scale plot trials, we are investigating low-disturbance methods for returning dense infestations of the grass to productive pastures and have significantly reduced its presence over two wet seasons. We have demonstrated that ash from grass fires does not reduce the efficacy of flupropanate, and that 20 mm of rain is all that is needed to push flupropanate into the soil. Trials have also confirmed that high levels of dry grass at the time of application of flupropanate do not reduce herbicide efficacy. We are continuing work on how to manage the grass in seasonally waterlogged areas. We are also investigating whether fertiliser could improve the quality of giant rat's tail grass, to make it attractive as fodder for cattle.

Boom-spray application of flupropanate at a trial site at Miriam Vale

Inspection of field trials on giant rat's tail grass at a technical training day, Miriam Vale

Spot application of flupropanate on giant rat's tail grass with no off-target damage

Collaborators

- Economic Development Queensland
- Biosecurity officers (particularly John Reeve and Nathan March)
- Gladstone Regional Council (including Rob Teakle, Lewis Heuvel, Kelvin Dawson and Glenn Cox)
- Landholders
- Brett Cawthray (landholder and contractor)

Key publications

Vogler, W, Carlos, E & Hosking, K 2017, 'Extending flupropanate use—spot application on perennial mission and gamba grass', *Proceedings of the 14th Queensland weed symposium*, The Weed Society of Queensland, Brisbane.

19. Management and ecology of fireweed (*Senecio madagascariensis*)

Project dates

July 2017 – June 2020

Project team

Joseph Vitelli, Kusinara Wijayabandara, Steve Adkins and Shane Campbell

Project summary

Fireweed (*Senecio madagascariensis* Poir.) is a short-lived perennial (sometimes annual) plant native to South Africa and Madagascar. It was introduced to Australia over 90 years ago, and spread throughout pastures along the coast of New South Wales and south-eastern Queensland. However, its distribution in Australia is now unclear due, at least in part, to its confusion with the native *S. lautus* complex.

Fireweed is difficult to eradicate and competes strongly with useful pasture species under a range of fertility conditions. Further, like many *Senecio* species, it produces pyrrolizidine alkaloids, which when ingested by livestock reduce growth and in severe cases cause mortality. Sheep and goats are reported as being less susceptible than cattle and horses to poisoning from pyrrolizidine alkaloids.

Through this three-year collaborative doctorate project with The University of Queensland, we are investigating:

- the reproductive output of fireweed in the Queensland environment
- its impact on native and introduced pasture plants
- determinants of invasiveness (in addition to reproductive capacity)
- management effectiveness.

In a foliar herbicide trial at Beechmont, a single application of Grazon™ Extra, Hotshot™ or Tordon™ RegrowthMaster controlled over 90% of the fireweed treated, while applications of the herbicides bromoxynil and Brush-Off™ respectively controlled 60% and 75% of the fireweed. A second application of each herbicide 3 months after the initial spraying controlled over 90% of the treated plants, with Grazon Extra and Tordon RegrowthMaster killing 100% of the fireweed plants..

Collaborators

- Kusinara Wijayabandara (PhD candidate), Steve Adkins and Shane Campbell (School of Agriculture and Food Sciences, The University of Queensland)
- Irene and Bruce Mills (property owners, Beechmont)

20. Ecology and management of *Chromolaena odorata* and *Clidemia hirta*

Project dates

July 2008 – June 2021

Project team

Simon Brooks, Kirsty Gough, Stephen Setter and Melissa Setter

Project summary

In this project, we support a range of stakeholders managing the former eradication target species *Chromolaena odorata* (Siam weed) and *Clidemia hirta* (Koster's curse). Trials are investigating seed-bank longevity, seed-bank depletion, age to maturity, germination requirements and herbicide efficacy.

In a pot trial, we assessed pre-emergent herbicides on the seeds of *C. odorata*. We assessed 14 herbicides for possible use across different environments and different types of agricultural and amenity land.

Field trials of buried packets of seeds of these two species will help us determine the longevity of soil seed-banks. A small amount of viable *C. odorata* seed was retrieved from a trial in the Dry Tropics after 8 years burial in four different soil types, even though no viable seed was found after 6 years. Retrievals from buried packets of *C. hirta* seed in the Wet Tropics reinforces field experiences that this species develops a persistent soil seed-bank, as around 30% of buried seed was viable after 8 years.

Collaborators

- Biosecurity Queensland officers
- Queensland Parks and Wildlife Service
- Mareeba Shire Council
- Johnstone Shire Council

Key publications

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

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*, vol. 29(2), pp. 71–77.

21. Eradication progress and biology of tropical weed eradication targets

Project dates

July 2008 – June 2021

Project team

Simon Brooks, Kirsty Gough, Stephen Setter and Melissa Setter

Project summary

In this project, we investigate the biological parameters influencing the field operations that are targeting tropical weeds for eradication. These parameters include seed-bank persistence, age to maturity and dispersal potential. We also assess control measures for these weeds.

Field trials investigating seed persistence of *Miconia calvescens*, *M. racemosa*, *M. nervosa* and *Mikania micrantha* (running for 4–8 years) have found persistent seed banks for all species. Also, our glasshouse trial of *Limnocharis flava* seed persistence under varying periods of immersion in water over 7 years recorded reduced seed viability in the driest annual treatments.

We are collating data on the growth to maturity and reproductive seasonality of invasive melastomes to refine guidelines for identifying and preventing seed-producing plants and assessing survey accuracy. The field data is supplemented by the results of glasshouse pot trials where seedlings are established at 3-monthly (seasonal) intervals and grown to flowering. In 2018, we established a field plot to measure the growth of *M. nervosa*.

We also develop and report on indicators of progress towards eradication using field data from the control teams.

The first flowering and leaf of *M. nervosa*

A pot trial to determine the life history parameters of *M. racemosa*

Collaborators

- National Tropical Weeds Eradication Program
- Biosecurity officers (North Region)

Key publications

Weber, JM & Brooks, SJ 2013, 'The biology of Australian weeds 62. *Limnocharis flava* (L.) Buchenau', *Plant Protection Quarterly*, vol. 28(4), pp. 101–113.

22. Herbicide application research

Project dates

July 2009 – June 2020

Project team

Wayne Vogler, Dannielle Brazier and Clare Warren

Project summary

The Australian Government Department of Agriculture is providing funding to test applications of low-volume, high-concentration herbicide (e.g. using splatter guns) on prickly acacia, rubber vine, chinee apple and gamba grass. We have completed a trial to determine the efficacy of glyphosate applied at seven different rates to control gamba grass. We are now continuing a further trial on more mature gamba grass stands using both glyphosate and flupropanate.

Another trial aims to improve herbicide efficacy on prickly acacia by identifying the optimum way to spray plants. The amount of required herbicide can be based on the surface area of one or both sides of plants and spraying can be undertaken on one or both sides of plants.

We have completed a trial that compares the efficacy of monthly applications (from December to May) of two herbicides [metsulfuron-methyl (Brush-off®) and triclopyr/picloram/aminopyralid (Grazon™ Extra)] to control rubber vine. This trial also determined any seasonal and environmental influences that may affect mortality. An additional trial is evaluating treatment methods on scattered and dense rubber vine populations.

We have established a trial on chinee apple that assesses the efficacy of five herbicides applied at two rates. We have also established demonstration sites for both chinee apple and prickly acacia to compare different application techniques, such as using backpack-style equipment or larger, ATV-mounted units. A series of herbicide trials on the control of night-blooming cereus (*Cereus uruguayanus*) is almost compete, with minor field work remaining.

Using a splatter gun to spray gamba grass near Mareeba

Applying herbicide to rubber vine using a splatter gun

Collaborators

- Northern Gulf Resource Management Group
- Desert Channels Queensland
- Central Highlands Regional Council
- Central Highlands Regional Resources Use Planning Cooperative
- Biosecurity officers
- Shane Campbell (The University of Queensland)

Key publications

Campbell, SD & Brazier, DA 2016, 'Developing additional herbicide control options for rubber vine (*Cryptostegia grandiflora* R.BR.), *Proceedings of the 20th Australasian weeds conference*, The Weeds Society of Western Australia, Perth, pp. 284–287.

Campbell, S, McMillan, H, Brazier, D, Setter, M & Setter, S 2019, 'Advancing splatter gun technology for rangeland weeds', *Proceedings of the 1st Queensland pest animal and weed symposium*, The Weed Society of Queensland, pp. 101–104.

23. Control packages for statewide weed eradication targets

Project dates

July 2008 – June 2020

Project team

Joseph Vitelli, Annerose Chamberlain, Natasha Riding and Anna Williams

Project summary

In this project, we aim to develop reliable and effective control options that can be integrated into eradication programs for priority weeds in Queensland.

Through an integrated control study in a sugarcane-growing area near Mackay, we are investigating the efficacy of agronomic practices for depleting the red witchweed soil

seed-bank and preventing further seed production over a 10-year period. Pre- and post-emergent herbicides are applied to sugarcane and are compared with catch crops, trap crops and fumigants. We established a new trial to determine whether seed depletion of red witchweed can be accelerated with a continuous, false-host soybean crop, punctuated with multiple applications of the fumigant ethylene.

To evaluate eradication efforts on infested properties, we buried 300 perforated PVC canisters each containing three sachets of red witchweed (each sachet containing ~100 seeds) at depths of 10 cm, 30 cm and 50 cm across 25 sites covering the spectrum of treatments (soybean, ethylene and dazomet) that are currently being applied separately and repeatedly or in combination on different topographies across the eight infested properties. We retrieved canisters after 24 and 36 months, and are continuing to assess seed viability.

The retrieval data for the efficacy trial shows encouraging trends. As seed burial depth increases from 0 cm to 50 cm, seed viability increases from 61% to 69%, 47% to 66%, 33% to 59% and 9% to 20% for the 6-month, 12-month, 24-month and 36-month retrieval periods respectively. Three annual applications of either ethylene gas, sorghum, dazomet or soybean reduced the red witchweed soil seed-bank viability to 1%, 1.3%, 5.3% and 6.5%, respectively, irrespective of seed burial depth. Doubling the age of the soybean crop in the field (from 6 weeks to 12 weeks) before its destruction accelerated the depletion of red witchweed seed by 30%.

False hosts and fumigants remain the most effective tools for depleting the soil seed-bank. The seed viability of red witchweed buried among sugarcane for 3 years ranged from 62% (0 cm burial depth) to 25% (50 cm burial depth).

A tractor-mounted ethylene-injection system used to accelerate depletion of the soil seed-bank of red witchweed

Collaborators

- Local governments
- Biosecurity Queensland officers (Michelle Smith and Tom Bowditch)
- The University of Queensland

24. Native and introduced pathogens of giant rat's tail grass

Project dates

February 2017 – June 2020

Project team

Joseph Vitelli, Claire Lock, David Holdom, Annerose Chamberlain, Jimmy Hoskings, Roger Shivas, Kaylene Bransgrove, Diana Leemon and Yu Pei Tan

Project summary

Sporobolus R.Br. is a genus of 186 accepted grass species and 12 unresolved species in tropical and subtropical areas of the world, including Africa, temperate Asia, tropical Asia, Australasia, North America and South America. In Australia, 18 species are endemic and a further 6 species are naturalised. In rangelands, *Sporobolus* species are not desirable pasture grasses and usually indicate a degraded grazing system. The few native species regarded as favourable fodder species (*S. actinocladus*, *S. caroli*, *S. mitchellii* and *S. virginicus*), due to their high protein content when fresh, do not provide much bulk. The introduced weedy *Sporobolus* grasses are a serious concern to the grazing industry of eastern Australia. They cost the industry an estimated $60 million per annum and have the potential to completely dominate pastures at the exclusion of most other species. These weeds are part of the *S. indicus* complex, which includes *S. pyramidalis* and *S. natalensis* (giant rat's tail grass), *S. fertilis* (giant Parramatta grass), *S. africanus* (Parramatta grass) and *S. jacquemontii* (American rat's tail grass).

This project has two components:

- use of molecular tools to better target weedy *Sporobolus* with classical biocontrol agents and to study the genetic diversity of *Sporobolus*
- further investigations into endemic Australian pathogens of *Sporobolus*.

To date, we have carried out 14 pathogen surveys of pasture, roadsides and forest verges across 64 *Sporobolus*-infested sites. The surveys have identified a total of 159 symptomatic tussocks belonging to 13 species of *Sporobolus*. These infected tussocks were removed from the field and transported to the Ecosciences Precinct. Of these, 134 plants displayed foliar disease symptoms yielding over 300 isolates.

Koch's postulates (used to establish causation between a putative pathogen and a disease) confirmed that three fungal isolates collected from the field were responsible for the disease symptoms observed on giant rat's tail grass. The three novel species of fungi (*Microdochium* sp. BRIP 65649, *Pestalotiopsis* sp. BRIP 66615 and *Neopestalotiopsis* sp. BRIP 66617) were found on hosts in the *S. indicus* complex. The novel identities of these isolates have been confirmed through phylogenetic analyses. Preliminary testing has shown that the three fungi play a role in seedling mortality of giant rat's tail grass. *Neopestalotiopsis* sp. BRIP 66617 was the most virulent of the three, killing 70% of inoculated giant rat's tail grass seedlings.

We have established an integrated management trial at Conondale to examine the use of wick-wipers and leaf smut in managing dense swards of giant rat's tail grass. Dense areas

of the grass were slashed, then crash-grazed to allow height differentiation between giant rat's tail grass and desirable grasses. We wick-wiped the giant rat's tail grass at varying concentrations of glyphosate and flupropanate, either alone or mixed. The presence of the leaf smut at the site is allowing us to collect preliminary data on how the leaf smut might be incorporated as part of an integrated management strategy. We ran a field day at the trial site in June 2019.

Collaborators

- Australian Government Department of Agriculture
- AgriFutures Australia
- New South Wales Department of Primary Industries
- Victoria Department of Jobs, Precincts and Regions
- New South Wales Weed Biocontrol Taskforce, via Rous County Council
- Bundaberg Regional Council (including Eric Dyke and James Anderson)
- Gladstone Regional Council (including Brett Cawthray, Glenn Cox, Melissa Hele and Rob Teakle)
- HQPlantations
- Trevor and Margaret Dawson (Taunton)

25. Influence of soil type on flupropanate availability for managing giant rat's tail grass

Project dates

February 2017 – June 2021

Project team

Joseph Vitelli, Annerose Chamberlain and Jimmy Hoskings

Project summary

The herbicide flupropanate (developed in the 1960s) is reported to have a long-lasting residual activity but is prone to movement within the soil horizons. Its selective residual activity (limiting the growth of emerging tussock grass seedlings), knockdown ability and availability (in both liquid and granular form) has made it the preferred herbicide for tussock weed management. Unfortunately, land managers are experiencing inconsistent levels of control and in some situations are spending over $50 000 without killing any plants.

To investigate this, we have commenced two trials. The first focuses on the effectiveness of flupropanate in a range of soils. The second will determine the flupropanate concentration required to effectively control or suppress tussock seedling emergence and the concentrations at which flupropanate begins to have adverse effects on competitive pasture emergents.

We established a pot trial involving five soil types (chromosol, dermosol, ferrosol, kurosol and vertisol) and two application methods (liquid and granular) to determine the residual behaviour of flupropanate. Almost 80% of applied flupropanate was recovered in bare soil 3 months after application irrespective of soil type, and there was no significant difference between flupropanate applied in granular and liquid formulations. At 12 months, flupropanate recovery was at 70%, irrespective of soil type or flupropanate formulation. In pots planted with giant rat's tail grass, the amount of flupropanate recovered in soil at 3 months was 47% for granular applications and 17% for liquid applications. No significant difference has been detected between soil types from samples analysed to date. At 12 months, recovery in soil was 30% and 8% for granular and liquid formulations, respectively. The amount of applied flupropanate in giant rat's tail grass biomass at 3 months was ~25% for granular and liquid treatment applications irrespective of soil type, increasing to 32% at 12 months for granular application treatments but decreasing to 17% at 12 months for liquid application treatments.

Though the data is preliminary, the total amount of flupropanate recovered (soil plus biomass) at 12 months was 63% for granular treatments and 31% for liquid treatments. We will commence a second in-vitro dose-response trial in July 2019 to determine the susceptibility of five *Sporobolus* species and five competitive pasture species to ten different flupropanate concentrations.

Collaborators

- Powerlink Queensland
- School of Earth and Environmental Sciences, The University of Queensland
- Peter Thompson (Elgin, Conondale)
- Judith Ruhle, (Jalbirri, Bongeen)
- Errol Stenzel, (Bunburra, Boonah)

26. Integrated control of parthenium in southern Queensland

Project dates

July 2016 – June 2021

Project team

Olusegun Osunkoya, K Dhileepan, Christine Perrett, Jason Callander and Boyang Shi

Project summary

Parthenium (*Parthenium hysterophorus* L.) is a noxious weed of grazing areas in Queensland and a Weed of National Significance in Australia. While its core infestation is in central and northern Queensland, parthenium is spreading further south and is emerging as a serious weed in southern Queensland. In collaboration with North Burnett Regional Council, we established demonstration (and nursery) sites in Monto and Gayndah. Currently, 7 of the 11 biocontrol agents for parthenium (the stem-galling *Epiblema* moth, the seed-feeding *Smicronyx* weevil, the stem-boring *Listronotus* weevil, the root-boring *Carmenta* moth, the sap-sucking planter hopper *Stobaera*, the summer rust *Puccinia melampodii* and the winter rust *Puccinia abrupta*) are now established.

The demonstration sites have been designed so that quantitative data on the management strategies for parthenium can be evaluated. They consist of control plots (biocontrol alone), low-frequency chemical control plots (1 herbicide application at the beginning of the season + biocontrol), best-practice chemical management plots (herbicide application 10–14 days post rainfall event + biocontrol) and best-practice pasture management plots (grazing + biocontrol). North Burnett Regional Council maintains the sites and undertakes herbicide applications as required.

Both sites are intensively surveyed across the growing season (November–May) to document the separate and interaction effects of biocontrol, chemical control and grazing management on weed abundance and pasture biomass. We also record densities of established biocontrol agents.

The project is partly funded (up to June 2019) by the Australian Government (through a National Partnerships Agreement) to support southern Queensland landholders in the management of parthenium, particularly in integrating conventional control and biocontrol. The project also extends on the work conducted as part of the parthenium biocontrol project, which was supported by Meat and Livestock Australia and involved redistribution of agents from central to southern Queensland (concluded September 2018).

Sampling parthenium density at Gayndah

Collaborators

- Professor Steve Adkins (The University of Queensland)
- Dr Raghu Sathyamurthy (CSIRO Ecosystem Dynamics, Ecosciences Precinct)
- North Burnett Regional Council
- Stephen Downey, biosecurity officer (South Burnett)
- Peter Trotter (Aspect UAV Imaging, Sunshine Coast)
- Dr Felipe Gonzalez (Australian Centre for Robotic Vision, School of Engineering, Queensland University of Technology)

Key publications

Adkins, S, Shabbir, A & Dhileepan, K (eds) 2018, *Parthenium weed: biology, ecology and management*, Invasives Series, CABI, Wallingford, United Kingdom.

Dhileepan, K, Callander, J, Shi, B & Osunkoya, OO 2018, 'Biological control of parthenium (*Parthenium hysterophorus*): the Australian experience', *Biocontrol Science and Technology*, vol. 28:10, pp. 970–988.

Osunkoya, OO, Akinsanmi, OA, Lim, LSA, Perrett, C, Callander, J & Dhileepan, K 2017, '*Parthenium hysterophorous* L. (Asteraceae) had limited impact on major soil nutrients and enzyme activity: is the null effect real or reflects data insensitivity?' *Plant and Soil*, vol. 420, pp. 177–194.

27. Using pest distribution to assess pest risk and prioritise management

Project dates

July 2018 – June 2019

Project team

Olusegun Osunkoya, Bradley Gray, Moya Calvert and Christine Perrett

Project summary

Since 2003, the Queensland Annual Pest Distribution Survey (APDS) has mapped the distributions of major weeds and pest animals in Queensland. The data is gathered from periodic interviews with on-ground pest managers.

In this project, we interrogate and analyse trends in the APDS dataset. We have now validated the surrogate estimates of invasiveness (i.e. the extent of the invaded range based on the number of local government areas and regions infested) used to determine pest risk (invasiveness × impact) in a previous research project on weed prioritisation (Osunkoya, Nicol et al. 2019; Osunkoya, Froese et al. 2019). We have also used the APDS data to extend and standardise the current distribution-based measure of invasiveness by an abundance-based measure. We are now assessing how these invasiveness indices have changed over the past decade at the state and regional levels, and what the environmental drivers of these changes are.

In addition, for major established weeds of Queensland, we are combining the APDS data with long-term herbarium records to derive standardised invasion curves at state and regional levels and are making these available to local governments as well as the public (e.g. as an addition to Biosecurity Queensland's interactive weed maps). Finally, we are also interrogating the APDS dataset to derive spatio-temporal invasion indices for Queensland's most important invasive animals, complementing our previous prioritisation of invasive plants.

Collaborators

- Claire Lock (Eco Logical Australia)
- Joshua Buru (Queensland University of Technology)
- Jens Froese (CSIRO Health and Biosecurity)
- Sam Nicol (CSIRO Land and Water)
- Queensland Herbarium

Key publications

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*, Meat & Livestock Australia Limited, Sydney.

Osunkoya, OO, Nicol, S, Perrett, C, Moore, K, Callander, J & Campbell, S 2019, 'A risk-based inventory of invasive plant species of Queensland, Australia: regional, ecological and floristic insights', *Austral Ecology*, vol. 44, pp. 1123–1138, ‹https://doi:10.1111/aec.12774›.

Osunkoya, OO, Froese, J & Nicol, S 2019, 'Management feasibility of established invasive plants species in Queensland, Australia: a stakeholder's perspective', *Journal of Environmental Management*, vol. 246, pp. 484–495.

Part 2: Pest animal management

28. Monitoring the efficacy of new rabbit biocontrol

Project dates

April 2014 – June 2020

Project team

Peter Elsworth and Michael Brennan

Project summary

Biocontrol viruses have been at the forefront of rabbit management for nearly 60 years. The successful reduction in numbers of and damage from rabbits has allowed environmental systems to regenerate and agricultural systems to be more profitable. It has also allowed rabbit control to be effective at the property and local landscape levels. However, this potential for control has often been neglected, because the success of the biocontrol is seen as sufficient. This is not the case, and rabbit populations continue to recover following biocontrol outbreaks, with resultant damage.

Control programs begin with an application of virus, and this should be followed up with mechanical or chemical control. Often the follow-up control does not occur, yet this is the key to achieving a long-term reduction in rabbit numbers. We have been monitoring the outcomes of biocontrol releases, with and without follow-up control, to assess optimal management strategies. Two recent case studies (at Wallangarra and Highfields) have shown that deliberate release of virus into rabbit populations has minimal effect in the short term and no effect if follow-up control does not occur. The mechanical control of removing breeding harbour is the key component of rabbit management and needs to be the main and first control tool used where possible.

Collaborators

- Tarnya Cox (New South Wales Department of Primary Industries)
- Tanja Strive (CSIRO)
- Vanessa MacDonald, Holly Hosie and Lachlan Marshall (Southern Queensland Landscapes)
- Nathan Ring and Greg Wilson (Darling Downs – Moreton Rabbit Board)
- Craig Magnussen (Southern Downs Regional Council)
- Jim O'Sullivan (Toowoomba Regional Council)

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*, vol. 140, pp. 1972–1981.

Strive, T, Wright, JD & Robinson, AJ 2009, 'Identification and partial characterisation of a new lagovirus in Australian wild rabbits', *Virology*, vol. 384, pp. 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*, vol. 44, p. 51.

29. Management of peri-urban deer in south-eastern Queensland

Project dates

July 2018 – June 2022

Project team

Michael Brennan, Matt Amos and Tony Pople

Project summary

The apparent increase in distribution and abundance of wild deer in peri-urban environments is causing growing concern for wildlife management authorities across Australia. Current control and monitoring methods are very limited. This project forms part of a larger project with interstate collaborators on deer management through the Centre for Invasive Species Solutions. We aim to evaluate control operations, investigate alternative management tools and strategies, refine monitoring techniques, determine seasonal movements of deer and improve community engagement.

In this project, we work with local governments in eastern Australia who are undertaking deer control through trapping and shooting. The research team and collaborators are primarily providing monitoring and data analysis. In more urbanised areas (such as Brisbane and Wollongong), faecal pellet counts are being used to determine population trend. In Wollongong, the rusa population continues to increase despite culling, but below the maximum rate. Peri-urban areas on the Sunshine Coast are monitored by a thermal imager used from a vehicle along road transects and by time-lapse remote cameras photographing broad areas on properties. These surveys have recorded a declining population of rusa and red deer, which are being culled by ground shooting.

Remote cameras have revolutionised monitoring of cryptic animals such as canids and deer. Grids of more than 35 cameras have been deployed in south-eastern and central Queensland to provide density estimates of rusa deer populations. New statistical techniques (spatial mark-recapture and presence–absence models) are used to analyse data from the thousands of images recorded. These estimates can be used to determine the proportion of the population removed by trapping and shooting, and to monitor the trend in comparison with uncontrolled areas.

Another survey technique gaining popularity and offered by commercial operators uses thermal and colour imagery from aircraft. Deer can be detected with airborne thermal imagery; however, detection probability is often unknown and this is essential for accurate monitoring. To address this, a collaborative project with Queensland University of Technology

will take drone surveys of deer populations that are monitored on the ground and the estimates will be compared. Detection probability can also be improved with machine learning rather than by relying on human assessment of imagery.

Collaborators

- Tony Cathcart and Mark Kimber (Sunshine Coast Regional Council)
- Darren Sheil (Moreton Bay Regional Council)
- Bree Galbraith (Gympie Regional Council)
- Grant Hamilton and Ashlee Sudholz (Queensland University of Technology)
- Dave Forsyth and Andrew Bengsen (New South Wales Department of Primary Industries)
- Dr Petra Skoien (Biosecurity Queensland)
- Perry Ward and Jess Doman (Seqwater)
- Leise Childs, Dave Mitchell and John Wyland (Livingstone Shire Council)
- Robyn Jones and Bill Manners (Brisbane City Council)
- Steve Burke and Cam Mulville (Marine Parks, Department of Environment and Science, Yeppoon)

Key publications

Amos, M, Baxter, G, Finch, N, Lisle, A & Murray, P 2014, 'I just want to count them! Considerations when choosing a deer population monitoring method', *Wildlife Biology*, vol. 20(6), pp. 362–370.

Amos, M, 2018, 'Boom and bust—a contrast of two ungulate industries', *Advances in conservation through sustainable use of wildlife: proceedings of a conference held in Brisbane, Australia*, The University of Queensland, Gatton.

Amos, M, Cathcart, A & Kimber, M 2019, 'Counting deer, not tourists, on the Sunshine Coast', *Proceedings of the 1st Queensland pest animals and weed symposium*, The Weed Society of Queensland, Gold Coast.

Forsyth, D, Pople, T, Page, B, Moriarty, A, Ramsey, D, Parkes, J, Wiebkin, A & Lane, C (eds) 2017, *2016 national wild deer management workshop proceedings*, Invasive Animals Cooperative Research Centre, Canberra.

30. Ecology and management of chital deer in northern Queensland

Project dates

July 2014 – June 2022

Project team

Tony Pople, Mike Brennan and Matt Amos

Project summary

In this project, we study aspects of the ecology and management of chital deer (*Axis axis*), which were established in northern Queensland in the late 1800s. Unlike many other invasive vertebrate species, their spread has been relatively slow. However, in the last 20 years, landholders have reported an increase in chital deer abundance and an expansion of their range to a point where they were considered major pests. To develop long-term management strategies, we need information on their impacts, their capacity for increase and spread, and control methods. Limiting factors are likely to be a combination of dingo predation and food supply, particularly availability of water and high-quality food.

We have placed satellite tracking collars on 35 chital deer hinds that were darted from helicopter. The collars provide hourly locations from satellite downloads. This data will show the habitat use of deer and should help to explain the highly clumped regional distribution of deer. Collared deer also had vaginal transmitters implanted. These indicate the birth of fawns and allow their survival to be monitored. Remarkably, in contrast to similar studies overseas, 10 fawns monitored over 2017–18 have had 100% survival.

Comparisons of soil and plant mineral contents in areas of high and low chital density indicate that soil phosphorous and sodium and zinc in food plants are important determinants of habitat selection in this region.

Continued monitoring of properties where chital have been culled and not culled indicates a slow population recovery and, so far, effective control. This control has been made cost-effective by heavy drought mortality and by populations being concentrated near homesteads.

A collared chital deer recovering from sedation

A sedated, collared chital hind being monitored prior to release

Collaborators

- Keith Staines and Glen Harry (Sporting Shooters Association of Australia)
- Kurt Watter (masters student, The University of Queensland)
- Dave Forsyth and Andrew Bengsen (New South Wales Department of Primary Industries)
- Carlo Pacioni and Luke Woodford (Arthur Rylah Institute, Victoria)
- Jordan Hampton (Ecotone Wildlife Veterinary Services)
- Tony Salisbury, Rodney Stevenson and Carl Anderson (Biosecurity Queensland)
- Ashley Blokland (Charters Towers Regional Council)
- Helene Aubault (Dalrymple Landcare)
- Rachael Payne (NQ Dry Tropics)
- Catherine Kelly, Ben Hirsch, Lin Schwarzkopf and Iain Gordon (James Cook University)

Key publications

Forsyth, D, Pople, T, Page, B, Moriarty, A, Ramsey, D, Parkes, J, Wiebkin, A & Lane, C (eds) 2017, *2016 national wild deer management workshop proceedings*, Invasive Animals Cooperative Research Centre, Canberra.

Forsyth, DM, Ramsey, DSL, Veltman, CJ, Allen, RB, Allen, WJ, Barker, RJ, Jacobson, CL, Nicol, SJ, Richardson, SJ & Todd, CR 2013, 'When deer must die: large uncertainty surrounds changes in deer abundance achieved by helicopter- and ground-based hunting in New Zealand forests', *Wildlife Research*, vol. 40, pp. 447–458.

Kilgo, JC, Ray, HS, Vukovich, M, Goode, MJ & Ruth, C 2012, 'Predation by coyotes on white-tailed deer neonates in South Carolina', *The Journal of Wildlife Management*, vol. 76, pp. 1420–1430, ‹https://doi: 10.1002/jwmg.393›.

31. Predation of chital deer and cattle by wild dogs in northern Queensland

Project dates

July 2016 – September 2019

Project member

Lee Allen

Project summary

Chital deer were introduced to Maryvale Station north of Charters Towers in the 1890s. Although their distribution and abundance has historically been limited, a recent increase in numbers and spread is concerning to producers. Preliminary investigations confirming the presence of chital deer remains in wild dog scats suggest that wild dog predation may influence chital distribution and abundance.

In this project, we investigated seasonal changes in the diet of wild dogs in an area where chital are long established and relatively abundant. We collected 611 scat samples between July 2016 and July 2018. Deer were found to be a significant dietary item consumed by wild dogs, although the frequency of occurrence of deer remains in scats declined over time (11–13%, 0.2–4.7% and 0–2.7% in the 2016, 2017 and 2018 surveys respectively). Chital deer remains were detected in 13.7% of the 227 scats collected in paddocks within 6 km of the Spyglass homestead, but in only 3.2% of the 375 scats collected in paddocks further away. These differences follow the observed decline in deer abundance away from homesteads. Few wild dog scats (4 of 611, ‹0.7%) were found to contain cattle remains, suggesting low rates of predation in this area. These findings are consistent with the observations that wild dogs selectively prey on deer when they are available, chital aggregate around homesteads to avoid predation, and cattle (calves) are infrequently consumed as prey.

Collaborators

- Tony Pople and Michael Brennan (Biosecurity Queensland)

Key publications

Allen, L, Goullet, M & Palmer, R 2012, 'The diet of the dingo (*Canis lupus dingo* and hybrids) in north-eastern Australia: a supplement to the paper of Brook and Kutt (2011)', *The Rangeland Journal*, vol. 34, pp. 211–217.

Allen, LR 2014, 'Wild dog control impacts on calf wastage in extensive beef cattle enterprises', *Animal Production Science*, vol. 54(2), p. 214.

Allen, L 2017, 'Is landscape-scale wild dog control the best practice?' *Australasian Journal of Environmental Management*, vol. 24(1), pp. 5–15.

32. Cluster fencing evaluation

Project dates

October 2013 – December 2021

Project team

Lee Allen, Peter Elsworth, Joe Scanlan and Tony Pople

Project summary

In this project, we monitor the abundance of kangaroos, wild dogs and other wildlife, as well as pasture biomass and condition, before and after the erection of cluster fences. The findings will provide empirical information to evaluate the cluster fence strategy. The monitoring was to be completed in 2019, but has been extended another 3 years.

Our monitoring compares pest abundance and pasture condition on individual properties within the Morven and Tambo clusters (the first two cluster fences completed in Queensland) with those of properties outside the clusters. There are several direct and indirect economic benefits of cluster fencing. However, its success will ultimately be determined by the extent to which livestock production improves relative to livestock production in comparable areas outside the cluster, less the cost of establishing and maintaining the cluster fence, plus the benefit of reduced pest animal populations.

Different approaches of Tambo and Morven cluster participants towards managing pest animals and differences in rainfall received during 2018–19 have produced variable trends in wildlife abundance. However, ongoing dry seasonal conditions have generally reduced wildlife populations in these landscapes. Similarly, the livestock production benefits anticipated from exclusion fencing have been limited and variable depending upon the intensity and effectiveness of pest management undertaken by cluster participants. Substantial rainfall received over the summer of 2018–19 in the Tambo district is expected to increase pasture and benefit livestock production and wildlife populations in this region.

Collaborators

- Philip Maher (Department of Natural Resources, Mines and Energy)
- Geoff Castle (University of Southern Queensland)
- Megan Star (Central Queensland University)

Key publications

Allen, L & Engeman, R 2014, 'Evaluating and validating abundance monitoring methods in the absence of populations of known size: review and application to a passive tracking index', *Environmental Science and Pollution Research*, vol. 22, pp. 2907–2915.

Allen, LR 2011, 'Losing the battle of protecting Australia's sheep herd from wild dogs', *15th Australasian vertebrate pest conference*, Invasive Animals Cooperative Research Centre, Sydney.

Allen, LR 2017, 'Managing pests with exclusion fences: progress and potential biodiversity benefits', *17th Australasian vertebrate pest conference*, Invasive Animals Cooperative Research Centre, Canberra.

33. Anti-predator behaviour in livestock

Project dates

July 2017 – July 2019

Project member

Lee Allen

Project summary

Experienced adult cattle generally repel wild dog attacks, but deaths of bites to calves and weaners can lead to significant and economic loss for farmers. In northern Australia, most calf loss occurs within 14 days of birth and 40–50% of deaths are attributed to unknown causes.

A recent joint study (known as 'CashCow') between the Department of Agriculture and Fisheries and The University of Queensland showed on average a 5% greater calf loss on properties where owners reported wild dogs to be a problem than on other properties. There was ~10% greater calf loss from first-calf cows than from mature cows, and substantially greater calf loss in northern Queensland than in other areas. However, there was no difference in calf loss between properties that had been baited for wild dogs several times per year and those that had been baited annually or not at all.

The CashCow study has prompted further research into calf loss, husbandry practices and how management interventions might reduce calf losses from wild dogs. In this project, we aim to investigate:

- anti-predator defences in calves, weaners and first-calf mothers
- whether defence behaviours can be learned from experienced associates
- whether experienced 'coacher cows' could be used to train or protect younger animals from wild dog attacks.

We use a remotely controlled taxidermist-prepared wild dog to stimulate anti-predator behaviour in cattle. The equipment is being fine-tuned, and investigations will now be run as a postgraduate project through James Cook University.

Collaborators

- Ben Hirsch and Wayne Morris (James Cook University)

Key publications

Kluever, BM, Breck, SW, Howery, LD, Krausman, PR & Bergman, DL 2008, 'Vigilance in cattle: the influence of predation, social interactions, and environmental factors', *Rangeland Ecology & Management*, vol. 61, pp. 321–328.

34. Peri-urban wild dogs

Project dates

April 2018 – June 2022

Project team

Matthew Gentle, Lana Harriott and James Speed

Project summary

Lethal control is an important tool in mitigating the impacts of predators on livestock, wildlife and pets. However, in peri-urban environments, the landscape-scale application of control methods is restricted by small landholdings, varied land use, high human density and diverse opinions. Because of this, control may need to focus on specific individuals, groups or impacts, rather than broadscale population reduction.

In this project, we aim to assess and refine strategies and to produce best-practice guidelines for the management of wild dogs in peri-urban areas. We are assessing canid pest ejectors (CPEs) containing 1080 or PAPP at five trial sites in the Gympie and Sunshine Coast local government areas. The data being collected includes the attractiveness of CPEs (e.g. encounter rates, number and percentage of dogs locating CPEs) and the acceptance or rejection of CPEs by each individual. Changes in the sightings or impacts reported to local authorities are captured as an outcome of control.

Also, we are comparing the costs and benefits of CPE deployment with those of conventional control methods (trapping and other tools). Project collaborators are assessing the value of the community-led planning approach for improving peri-urban pest animal management. Community engagement will complement ecological research and help to identify acceptable management options for wild dogs in these environments.

Wild dog interest in a canid pest ejector

Collaborators

- Sunshine Coast Regional Council
- Gympie Regional Council
- Brisbane City Council
- HQPlantations
- Griffith University
- Landholders
- Centre for Invasive Species Solutions
- New South Wales Department of Primary Industries

Key publications

Gentle, M, Allen, BL & Speed, J 2017, *Peri-urban wild dogs in north-eastern Australia: ecology, impacts and management*, PestSmart Toolkit publication, Centre for Invasive Species Solutions, Canberra, Australia.

Harriott, L, Gentle, M, Traub, R, Soares Magalhaes, RJ & Cobbold, R 2019, 'Zoonotic and economically significant pathogens of peri-urban wild dogs across north-eastern New South Wales and south-eastern Queensland, Australia', *Wildlife Research*, vol. 46(3), pp. 212–221.

McNeil, AT, Leung, LKP, Goullet, MS, Gentle, M & Allen, BL 2016, 'Dingoes at the doorstep: home range sizes and activity patterns of dingos and other wild dogs around urban areas of north-eastern Australia', *Animals*, vol. 6(8), p. e48.

35. Non-target impacts of 1080 pig baits

Project dates

June 2014 – June 2020

Project team

Peter Elsworth, Joe Scanlan and Matthew Gentle

Project summary

Effective feral pig control in Queensland—to protect agriculture and the environment—relies heavily on 1080 bait. However, there is not sufficient formal data to support the future registration by the Australian Pesticides and Veterinary Medicines Authority of 1080 baits prepared from fresh meat (to be distributed from the air) and from fruit and vegetables. In this project, we have collected efficacy data on feral pig populations, the identity of non-target species visiting and consuming bait material, population counts of theoretically susceptible birds, and activity of varanids before and after baiting. We used control sites to ensure that treatment (baiting) effects, if any, can be identified.

We undertook field studies in areas of Queensland where 1080 baiting for feral pigs is common:

- Ingham—banana and mango substrates in horticulture and canefields
- Gore—meat substrate in sheep production enterprises
- Moonie—meat substrate in conservation lands
- Greenvale—meat substrate in cattle enterprises
- Hebel and Hungerford—meat substrate in conservation and cattle production areas.

Through the intensive use of remote cameras, we have collected a large volume of data. We are continuing to collate and analyse these studies, but the results to date suggest there is little impact to populations of non-target species. This information will be used to ensure that control programs for feral pigs are safe and effective.

Collaborators

- Charters Towers Regional Council
- Hinchinbrook Shire Council
- Herbert Cane Productivity Services
- Queensland Parks and Wildlife Service
- Landholders

Key publications

Cremasco, P, Gentle, M, Wilson, CJ, Di Bella, L & Buckman, M 2016, 'Feral pig baiting with fruit in the Wet Tropics', *Proceedings of the 5th Queensland pest animal symposium*, Townsville, pp. 103–106.

Cremasco, P & Bacchiella, D 2017, 'A strategy for effectively managing feral pig impacts in agricultural enterprises in northern Queensland', *Proceedings of the 17th Australasian vertebrate pest conference*, Invasive Animals Cooperative Research Centre, Canberra, p. 141.

Millar, A, Gentle, M & Leung, L 2015, 'Non-target species interaction with sodium fluoroacetate (1080) bait for controlling feral pigs (*Sus scrofa*) in southern Queensland', *Pacific Conservation Biology*, vol. 21, pp. 158–162.

36. Feral cat ecology and management

Project dates

June 2014 – June 2020

Project team

Matthew Gentle, Bronwyn Fancourt, Christine Zirbel, James Speed and Glen Harry

Project summary

Feral cats threaten wildlife, agriculture and human health through predation, competition and the spread of infectious diseases. Control of feral cat populations using intensive measures (such as trapping) can be effective, but these are resource-intensive and generally unsuitable for broadscale use. In this project, we investigate and test options for the broadscale control of feral cats in Queensland environs. Through collaboration, we are also investigating the response to and benefits of cat removal on prey species.

Through monitoring, we assessed the potential risk to non-target species from a chipolata-style 1080 feral cat bait, Eradicat®. More than 100 baits deployed at Currawinya National Park (south-western Queensland), and Main Range National Park and Girraween National Park (south-eastern Queensland) were monitored with remote cameras for 14 days to determine bait uptake rates as well as target and non-target species interactions with baits. This bait uptake data complements that from similar trials in central and northern Queensland.

Trapping at Currawinya National Park yielded 17 cats, which were fitted with GPS collars and released. The GPS location data collected will help us understand the fine-scale movements of feral cats and identify areas of high cat activity for targeting in control programs. Unfortunately, the trial to test Eradicat efficacy during winter 2018 was cancelled because the number of collared cats remaining alive was not sufficient to robustly measure baiting mortality.

A 5.3 kg male cat fitted with a GPS collar in April, tracked to its resting location in a hollow tree in July

Collaborators

- Shellie Cash, Barry Nolan and John Augusteyn (Queensland Parks and Wildlife Service, Department of Environment and Science)
- Jane Oakey and Craig Smith (Biosecurity Queensland, Coopers Plains)
- Jessica Guidotti and Diana Fisher (The University of Queensland, St Lucia)
- Neal Finch (Department of Environment and Science)
- Greg Falzon (Deves Falzon Pty Ltd)
- Various private landholders

Key publications

Fancourt, B, Speed, J & Gentle, M 2016, 'Uptake of feral cat baits in eastern Australia', *Proceedings of the 5th Queensland pest animal symposium*, Townsville, pp. 99–102.

Fancourt, BA, Cremasco P, Wilson, C & Gentle, M 2019, 'Do dingoes supress feral cats? spatial and temporal activity of sympatric feral cats and dingoes in central Queensland', *Proceedings of the 1st Queensland pest animal and weed symposium*, Gold Coast, pp. 50–51.

Wilson, C, Fancourt, B, Speed, J & Gentle, M 2017, 'Home range and habitat utilisation of feral cats (*Felis catus*) in central Queensland', *Proceedings of the 17th Australasian vertebrate pest conference*, Invasive Animals Cooperative Research Centre, Canberra, p. 99.

Part 3: Research services

37. Chemical registration—providing tools for invasive pest control

Project dates

July 2012 – June 2020

Project team

Joe Vitelli and David Holdom

Project summary

Biosecurity Queensland holds permits for the 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 for controlling invasive species outside of crops.

Eight new permits were issued to Biosecurity Queensland during 2018–19 by the Australian Pesticides and Veterinary Medicines Authority (APVMA). Seven permits related to weeds (African boxthorn, lippia, red witchweed, salvinia, thunbergia, water hyacinth, water lettuce and water mimosa) and one permit was for the control of wild dogs and foxes. A further three permits (for the control of kudzu, salvinia and feral cats) have been lodged with the APVMA.

Collaborators

- Local governments
- Seqwater
- Agribusiness (including Sumitomo Chemical, Nufarm Australia, Macspred and Corteva Agriscience)
- Department of Environment and Science
- Department of Transport and Main Roads
- Biosecurity Queensland officers, including Sonia Jordan, Steve Csurhes, Craig Hunter, Michael Graham, Lyn Willsher, John Reeves, Stacey Harris and Michelle Smith

Key publications

Eight new permits were issued by the APVMA to Biosecurity Queensland during the 2018–19 financial year, and one of the permits issued to the New South Wales Department of Primary Industries that year includes Queensland as a jurisdiction:

1. Permit (PER14357) Various products/Various crops/Witchweeds, expires 31 August 2023, ‹http://permits.apvma.gov.au/PER14357.PDF›.
2. Permit (PER14361) Ethylene/Infected premises/Witchweeds, expires 31 March 2022, ‹http://permits.apvma.gov.au/PER14361.PDF›.
3. Permit (PER10540) 2,4-D amine, glyphosate and metsulfuron/Pasture and fallow (floodplains)/Lippia, expires 31 July 2020, ‹http://permits.apvma.gov.au/PER10540.PDF›.
4. Permit (PER10557) Nufarm Arsenal® Xpress Herbicide/Non-crop areas/Thunbergia, expires 30 September 2023, ‹http://permits.apvma.gov.au/PER10557.PDF›.
5. Permit (PER86933) Glyphosate/Water impoundments and associated channels/Salvinia, water hyacinth, water lettuce, expires 30 September 2023, ‹http://permits.apvma.gov.au/PER11540.PDF›.
6. Permit (PER80472) Glyphosate, metsulfuron methyl and amitrole/Aquatic situations/Water mimosa and dead and awake, expires 31 March 2024, ‹http://permits.apvma.gov.au/PER80472.PDF›.
7. Permit (PER81752) Glyphosate/Agricultural non-crop areas and pastures/African boxthorn, expires 31 March 2024, ‹http://permits.apvma.gov.au/PER81752.PDF›.
8. Permit (PER14004) Strychnine/Wild dogs and foxes, expires 31 March 2022, ‹http://permits.apvma.gov.au/PER14004.PDF›.
9. Permit (PER9792) Consolidated flupropanate, fluazifop, glyphosate/Non-crop situations/Tussocky grasses, expires 30 November 2025, ‹http://permits.apvma.gov.au/PER9792.PDF›.

38. Pest management chemistry

Project dates

Ongoing

Project team

Stephen Were, Patrick Seydel, Alyson Herbert and Chien Cao

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 eco-toxicological investigations into the use of vertebrate pesticides. The project is undertaken in Biosecurity Queensland's Chemical Residue Laboratory at the Queensland Government's Health and Food Sciences Precinct at Coopers Plains, Brisbane.

Forensic toxicology

Over the year, our laboratory performed more than 70 investigations into possible animal poisonings—51 for sodium fluoroacetate, 11 for strychnine, 8 for anticoagulants and 1 for metaldehyde. While most investigations related to domestic dogs and cats, some involved livestock and macropods.

Also, 94 bait samples were tested for research trials on controlling feral cats.

Formulation chemistry

During the year, our formulation facility produced 1710 L of 1080 (36 g/L) pig bait solution for use in baiting programs coordinated by Biosecurity Queensland and local governments.

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

External funding

Research and development contracts

Project/research area	Funding body	Funds ($)
Aquatic weed management	CSIRO	16 000
Biocontrol of cat's claw creeper	Seqwater	90 000
Biocontrol of parthenium	Meat and Livestock Australia	146 000
Biocontrol of parthenium	Australian Government	185 000
Biocontrol of pasture weeds, Vanuatu	Landcare Research New Zealand	23 000
Biocontrol of parkinsonia	CSIRO	42 000
Biocontrol of *Cylindropuntia* spp.	New South Wales Department of Primary Industries	42 000
Biocontrol of mother-of-millions	New South Wales Department of Primary Industries	113 000
Biocontrol of prickly acacia	AgriFutures Australia	36 000
Endemic pathogens of giant rat's tail grass	AgriFutures Australia	13 000
Biocontrol of giant rat's tail grass	AgriFutures Australia	33 000
Giant rat's tail grass flupropanate control	Australian Department of Industry, Innovation and Science (AusIndustry)	25 000
Giant rat's tail grass flupropanate control	Powerlink	8 000
Giant rat's tail grass management in central Queensland	Gladstone Regional Council	20 000
Giant rat's tail grass management in Aldoga, Gladstone State Development Area	Economic Development Queensland	13 000
Giant rat's tail grass management	Australian Government	180 000
Herbicide control of rangeland weeds	Australian Government Department of Agriculture	118 000
Wild dog and deer management	Centre for Invasive Species Solutions	165 000
Cluster fencing evaluation	Centre for Invasive Species Solutions	60 000
Total		**1 328 000**

Land Protection Fund

Project/research area	Funds ($)
Weed seed dynamics	26 000
Herbicide application research	94 000
Biocontrol of bellyache bush	165 000
Biocontrol of prickly acacia	212 000
Biocontrol of cat's claw creeper	114 000
Biocontrol of cactus	149 000
Biocontrol of mother-of-millions	40 000
Biocontrol of parthenium	65 000
Biocontrol of giant rat's tail grass	53 000
Rearing and release of weed biocontrol agents	166 000
Efficacy of parthenium control	116 000
Prickly acacia population ecology	38 000
Prioritising pest management	39 000
Water weed ecology and management	167 000
Modelling decision support	16 000
Feral deer best-practice research	292 000
Wild dog best-practice research	273 000
Rabbit best-practice research	19 000
Non-target impacts of 1080 feral pig baits	14 000
Pesticide authorities	117 000
Pest management chemistry and chemical registration	86 000
Total	**2 261 000**

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Publications and presentations

Journal articles

Aigbedion-Atalor, P, Day, MD, Idemudia, I, Wilson, DD & Paterson, ID 2019, 'With or without you: stem-galling of a tephritid fly reduces the vegetative and reproductive performance of the invasive plant *Chromolaena odorata* (Asteraceae) both alone and in combination with another agent', *BioControl*, vol. 64, pp. 103–114.

Aigbedion-Atalor, PO, Idemudia, I, Adom, M & Day, M 2018, 'First record of a specialist folivore of *Chromolaena odorata* (Asteraceae) in Togo, and indices of its range expansion in Nigeria: implications for biological control', *Biocontrol Science and Technology*, vol. 28, pp. 805–810.

Aigbedion-Atalor, PO, Idemudia, I, Witt, BRA & Day, MD 2019, 'First record of the impact of the parasitism of *Cecidochares connexa* (Diptera: Tephritidae) by a solitary larval ectoparasitoid in West Africa: cause for concern?', *Journal of Plant Diseases and Protection*, vol. 126, pp. 93–95.

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Dhileepan, K 2018, 'Weed biocontrol program', *Queensland Invasive Plants and Animals Committee (AIPAC) meeting*, Brisbane, 30 November.

Dhileepan, K 2019, 'Biological control of cat's caw creeper', *Gympie & District Landcare Group biocontrol forum*, Gympie, 22 May 2019.

Elsworth, P 2019, 'Rabbits and calicivirus', *South East Queensland Pest Animal Management Group*, Ipswich, 3 April.

Fancourt, BA 2019, 'Do dingoes supress feral cats? spatial and temporal activity of sympatric feral cats and dingoes in central Queensland', *Queensland Dog Offensive Group committee meeting*, Brisbane, 3 June.

Fancourt, BA 2019, 'Evaluation of different strategies for the landscape control of feral cats', *Northern Tablelands Regional Pest Animal Committee meeting*, Glen Innes, New South Wales, 17 June.

Fancourt, BA 2019, 'Queensland research update', *Seventh Feral Cat Taskforce meeting*, Canberra, 7–8 February.

Fancourt, BA 2019, 'Tackling feral cats and their impacts', *Parks Australia science forum*, Canberra, 4 June.

Gentle, M 2019, 'PAPP in wild dog baits and CPEs for peri-urban baiting programs', *South East Queensland Pest Animal Management Group*, Ipswich, 3 April.

Gentle, M, Harriott, L & Speed, J 2019, 'Management of wild dogs and deer in peri-urban landscapes: strategies for safe communities', *Centre for Invasive Species Solutions wild dog meeting*, Dutton Park, 12 March.

Harriott, L 2018, 'Management of wild dogs and deer in peri-urban landscapes: strategies for safe communities', *South East Queensland Pest Animal Management Group*, Boonah, 3 October.

Harriott, L 2019, 'Use of canid pest ejectors for peri-urban wild dog management', *Mary River Environs Pest Animal Group*, Nambour, 5 June.

Harriott, L 2019, 'Use of canid pest ejectors for peri-urban wild dog management', *South East Queensland Pest Animal Management Group*, Ipswich, 3 April.

Kronk, A 2019, 'Overview of biological control processes', *Weed information day*, Tropical Weeds Research Centre, Charters Towers, 11 May.

Taylor, DBJT 2019, 'Biological control of prickly acacia: galling agents from Africa', *Prickly Acacia Alliance*, Brisbane, 19 June.

Vitelli, JS 2018, 'Navua sedge: its biology, control options and implications to management', *Navua Sedge Malanda Working Group workshop*, Malanda, 12 October.

Vitelli, JS 2018, 'Red witchweed (*Striga asiatica* (L.)) in Australia', *Delegates of the Argentinian National Service of Agri-Food Health and Quality (SENASA)*, Ecosciences Precinct, Dutton Park, 26 July.

Vitelli, JS 2019, 'Biological control investigations', *GRT best practice technical workshop*, Ecosciences Precinct, Dutton Park, 12 February.

Vitelli, JS 2019, 'Control treatment options', *GRT best practice technical workshop*, Ecosciences Precinct, Dutton Park, 12 February.

Vitelli, JS 2019, 'Current GRT research and interim findings', *GRT best practice technical workshop*, Ecosciences Precinct, Dutton Park, 12 February.

Vitelli. JS 2019, 'Current GRT research and interim findings', *Powerlink land maintenance forum*, Powerlink Queensland, Virginia, 13 March.

Vitelli, JS 2019, 'Current practices overview for scenarios 4–6', *GRT best practice technical workshop*, Ecosciences Precinct, Dutton Park, 13 February.

Vitelli, JS 2019, 'Identification of GRT', *GRT best practice technical workshop*, Ecosciences Precinct, Dutton Park, 12 February.

Vitelli, JS 2019, 'Red witchweed, background information', *Red witchweed eradication program efficacy review*', Ecosciences Precinct, Dutton Park, 8 April.

Vitelli, JS 2019, 'Research gaps and future priorities', *GRT best practice technical workshop*, Ecosciences Precinct, Dutton Park, 13 February.

Vitelli, JS 2019, 'Research priorities for red witchweed', *Red witchweed eradication program efficacy review*', Ecosciences Precinct, Dutton Park, 8 April.

Vitelli, JS 2019, 'Research update: looking back at 35 years', *The Weed Society of Queensland, 44th AGM*, Ecosciences Precinct, Dutton Park, 22 February.

Vitelli, JS 2019, 'RWW efficacy trial', *Red witchweed eradication program efficacy review*, Ecosciences Precinct, Dutton Park, 8 April.

Vitelli, JS 2019, 'RWW eradication trials efforts', *Red witchweed eradication program efficacy review*, Ecosciences Precinct, Dutton Park, 8 April.

Vogler, W 2018, 'GRT fundamentals and management', *Giant rat's tail grass and other weeds forum*, Isaac Regional Council and Fitzroy Basin Association, Nebo, 19 October.

Vogler, W 2018, 'Prickly acacia ecology for management', *Desert Channels Queensland/DAF BMP workshop*, Barcaldine, 14–15 November.

Vogler, W 2019, 'GRT ecology and management', *GRT technical training workshop*, Mirani, 30 May.

Vogler, W 2019, 'GRT ecology and management', *GRT technical training workshop*, Miriam Vale, 28 May.

Vogler, W 2019, 'GRT fundamentals and management', *Giant rat's tail grass management forum*, Mackay Regional Pest Management Group, Mirani, 3 May.

Vogler, W 2019, 'GRT fundamentals and management', *Giant rat's tail grass and other weeds forum*, Isaac Regional Council and Fitzroy Basin Association, Clermont, 20 February.

Vogler, W 2019, 'GRT fundamentals and management', *Pest Management Advisory Committee meeting*, Mareeba Shire Council, Mareeba, 14 May.

Vogler, W 2019, 'GRT management', *Grazing land management forum*, Reef Catchments, Mackay, 28 March.

Lectures and seminars

Bickel, TO 2019, *Weed Science PLNT3012/6894: aquatic plant ecology and management*, The University of Queensland, Gatton, 8 April.

Brazier, DA 2018, *Applying herbicides*, Certificate II agriculture students from School of Distance Education, Charters Towers, 26 July.

Brooks, SJ 2018, *Applying herbicides*, Certificate II agriculture students from School of Distance Education, Charters Towers, 26 July.

Brooks, SJ 2018, *Research on eradication target species*, The University of Queensland students, Charters Towers, 11 July.

Day, M, 2018, *Biological control of weeds*, Departure of Agriculture, Bangkok, 6 July.

Day, M 2018, *Success in weed biocontrol and options for Thailand*, Departure of Agriculture, Bangkok, 6 July.

Day, M 2018, *Weed biological control: opportunities for Australia and ACIAR*, Australian Centre for International Agricultural Research, Canberra, 16 October.

Day, M 2019, *Biological control of weeds*, The University of Queensland, Gatton, 29 April.

Dhileepan, K 2018, *Biological control of parthenium weed: the Australian experience*, University of Agricultural Sciences, Bangalore, India, 29 September.

Dhileepan, K 2019, *Weed Science PLNT3012/6894: biological control of weeds 2*, The University of Queensland, Gatton Campus, 29 April.

Elsworth, P 2019, *Vertebrate biocontrol*, Veterinary School, The University of Queensland, Gatton, 25 March.

Gentle, M 2019, *Vertebrate pests—overview and control strategies*, School of Veterinary Science, The University of Queensland, Gatton, 18 March.

Harriott, L 2018, *Personal stories on One Health: an ecological approach*, School of Veterinary Science, The University of Queensland, St Lucia, 24 July.

Pollard, K 2018, *Classical biological control of invasive species—cat's claw creeper as a case study*, University of Asuncion, Paraguay, 29 October.

Pukallus, K 2018, *Overview of biological control at TWRC*, The University of Queensland students, Tropical Weeds Research Centre, Charters Towers, 11 July.

Vogler, W 2018, *What do you mean I am responsible for biosecurity?*, The University of Queensland students, Tropical Weeds Research Centre, Charters Towers, 11 July.

Vogler, W 2019, *GRT fundamentals and insights for management*, Beef Connect webinar, 27 March.

Field days

Brooks, SJ 2018, 'Splatter gun demonstration', *Dalrymple Landcare weed information day*, St Anns, Belyando Crossing, 22 August.

Brooks, SJ 2019, 'Weed seed longevity', *Weed spotter training and weed information day*, Charters Towers, 11 May.

Elsworth, P 2019, 'Rabbit control: warren ripping demonstration', *Rabbit management field day*, Highfields, 19 June.

Elsworth, P 2019, 'Rabbit control: warren ripping demonstration', *Rabbit management field day*, Logan, 27 June.

Elsworth, P 2019, 'Rabbit surveys and control', *Rabbit management field day*, Dalveen, 17 January.

Fancourt, BA 2019, 'Evaluation of control options for the landscape control of feral cats', *GLENRAC ferals in focus field day*, Dundee, New South Wales, 11 May.

Pukallus, K 2018, 'Overview of biological control at TWRC & future agents', *St Anns weed field day*, Collinsville, 22 August.

Pukallus, K 2019, 'Department of Agriculture and Fisheries display', *Northern Beef Expo*, Charters Towers, 7–8 June.

Vitelli, JS 2019, 'Current research into GRT management with herbicides and promising GRT pathogens', *AgForce, Coochin Creek Co-Op and Sunshine Coast Regional Council giant rat's tail grass field day*; also paddock walk and demonstration at Elgin Station, Conondale, 19 June.

Vogler, W 2019, 'GRT ecology and management', *DAF and Gladstone Regional Council GRT field day*, Miriam Vale, 8 June.

STEM Professionals in Schools

Pukallus, K & Kronk, A 2018, 'Dung beetle races and animal poo puzzler', *Under 8's day*, Distance Education Campus, Charters Towers, 2 November.

Pukallus, K & Kronk, A 2019, 'Science in action', *Under 8's day*, Millchester State School, Charters Towers, 30 May.

Technical highlights
Invasive plant and animal research 2018–19

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