Rural R&D for Profit Program

RnD4Profit-14-01-040 Fast-tracking and maximising the long-lasting benefits of weed biological control for farm productivity
Final Report

Meat & Livestock Australia Ltd

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Acknowledgements

The project was only possible due to the partnerships with numerous organisations and the leaders of the sub-projects.

This project wishes to acknowledge and thank Meat & Livestock Australia (MLA) as managing partner, and the following participating partner agencies and sub-project leaders, who have been passionate and committed to their work:

- NSW Department of Primary Industries (Dr Andrew McConnachie and Dr Kerinne Harvey)
- CSIRO Health and Biosecurity (Dr Louise Morin and Dr Raghu Sathyamurthy)
- Agriculture Victoria (Greg Lefoe)
- Queensland Department of Agriculture and Fisheries (Dr K Dhileepan)
- Primary Industries and Regions, South Australia (Dr John Heap).

Cover photo: Weeds are a problem at scale. People are needed as well as agents to hasten spread and so impact from biological control. Collecting gorse soft shoot moth at Melton Mowbray, Tasmania, for redistribution to Victoria, NSW and South Australia, 14 February 2017. Photo: Raelene Kwong

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Note: the department will publish the final report on its website but will not publish the appendices

Plain English summary

Fast-tracking and maximising the long-lasting benefits of weed biological control for farm productivity

Widespread weeds cost Australian agriculture more than $4.5billion a year.

The *Fast-tracking and maximising the long-lasting benefits of weed biological control for farm productivity* project (*Fast-tracking* project) 2016–18, funded under round one of the Rural R&D for Profit program, aimed to realise significant productivity and profitability improvements for primary producers by focusing on one piece of the national weed management puzzle – biological control.

History has shown biological control (biocontrol) is the most cost-effective, self-sustaining weed management technology currently available. The collective national return on biocontrol program investment by 2006 was at least 23:1, which is unparalleled for any other widespread weed management (Page and Lacey, 2006).

At its most basic level biological weed control can be defined as:

… the use of the invasive plant's naturally occurring enemies, to help reduce its impact.

Source: http://www.environment.gov.au/biodiversity/invasive/weeds/management/biological-control.html

Plants that have become weeds in Australia are rarely invasive and troublesome in their native (natural) range. In their native range plant populations are regulated by a variety of natural enemies, such as insects and pathogens (disease-causing organisms, such as fungi and bacteria), which attack the seeds, leaves, stems and roots of a plant. When plants are introduced to a location where these natural enemies do not occur, their populations can grow unchecked to a level where they are regarded as weeds.

A key advantage of biocontrol over other weed control options (e.g. chemical, mechanical and grazing pressure) is that when natural enemies (biological control agents) are widely established they exist permanently in the ecosystem and are mostly self-replacing.

Objectives

The project aimed to fast-track biological weed control to subsequently improve agricultural production and profitability by:

- conducting research and delivery on six national priority agricultural weeds (parkinsonia, parthenium, blackberry, silverleaf nightshade, *Cylindropuntia* spp. and gorse) and associated biocontrol agents, and
- improving the efficiency of information generation (via a partnership model for research, delivery and funding) and information exchange (via an online biocontrol repository and smartphone application).

Through eight interlinked sub-projects, the *Fast-tracking* project aimed to contribute to:

- greatly increasing the on-farm populations of eight weed biocontrol agents
- reducing weed competition and herbicide use across more than 25 million hectares
- reducing the densities of the six target weeds across northern and southern Australia
- increasing long-term annual yield and reducing annual weed control costs
- improving agricultural natural resource management nationally
- informing producers of weed management options
- establishing a new collaborative national approach to weed biocontrol.

Methods – the weed biocontrol discovery-to-delivery pipeline

Delivering biocontrol agents into the field is a key challenge of the discovery-to-delivery research, development and extension (RD&E) pipeline (Figure 1), which involves researching and discovery of potential agents, host-specificity testing (to ensure each agent attacks only the targeted weed, not desired plants), rearing and releasing (delivering) biocontrol agents, and monitoring establishment and impact. Where success is achieved, field collections and redistribution can occur to hasten the spread and, hence, impact at scale.

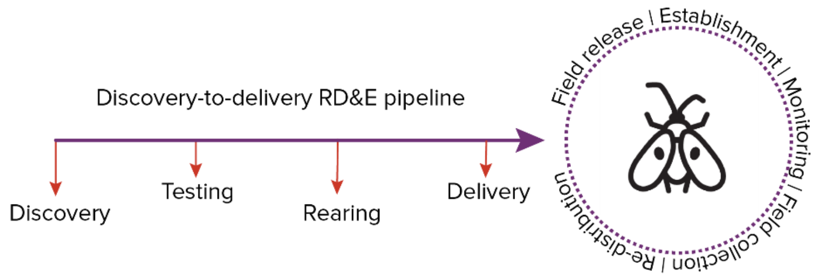


Figure 1. Conceptual model of the weed biocontrol discovery-to-delivery RD&E pipeline.

This scientifically rigorous approach applies proven, internationally accepted scientific principles for the discovery-to-delivery RD&E pipeline.

Several of the *Fast-tracking* sub-projects worked predominantly in the discovery and testing phases of the RD&E pipeline (e.g. silverleaf nightshade, blackberry and Cylindropuntia), while others focused on rearing and delivery activities (including field collection and redistribution), where successful populations of existing agents had been established in other regions during the past (e.g. parthenium, parkinsonia, gorse and Cylindropuntia).

In conventional biological control programs, the discovery-to-delivery pipeline can take many years to achieve on-ground impact. The *Fast-tracking* project undertook to speed up the process and enable impact at scale by collectively utilising and developing financial, human (expertise and skills) and infrastructure resources in a coordinated and sustained approach.

Improving the consistency of effort for weeds RD&E through a shared investment framework was explored by reviewing existing models locally and internationally and developing a partnership model for research and development funding, which has been piloted in New South Wales (NSW).

The efficiency of information generation and information exchange has been improved by utilising existing information technology approaches to develop a one-stop-shop repository for weed biocontrol knowledge and information, housed on the Atlas of Living Australia (ALA) website (Australian Biocontrol Hub). These information generation and exchange tools have been road-tested with other sub-project teams and more than 200 producers across southern Australia.

> "It's impractical and unrealistic to expect a halt in spread or any significant retraction in a weed's infestation, effected by biocontrol agents, within a fraction of the time it took to become problematic."

Survey participant, Commonwealth Government

Outcomes

The *Fast-tracking* project drew together stakeholders across regional, state and international boundaries, bringing together resources from more than 120 organisations and working alongside more than 200 land managers (see Figure 2 and Figure 3).

Figure 3. Location and type of collaborator associated with the *Fast-tracking* project outside Australia.

Figure 2. Location and type of collaborator associated with the *Fast-tracking* project within Australia.

The investment in the *Fast-tracking* project has provided a range of agents for the control of *Cylindropuntia* spp., gorse, parkinsonia and parthenium weed, and these biocontrol agents are expected to deliver more profitable grazing over the next 30 years.

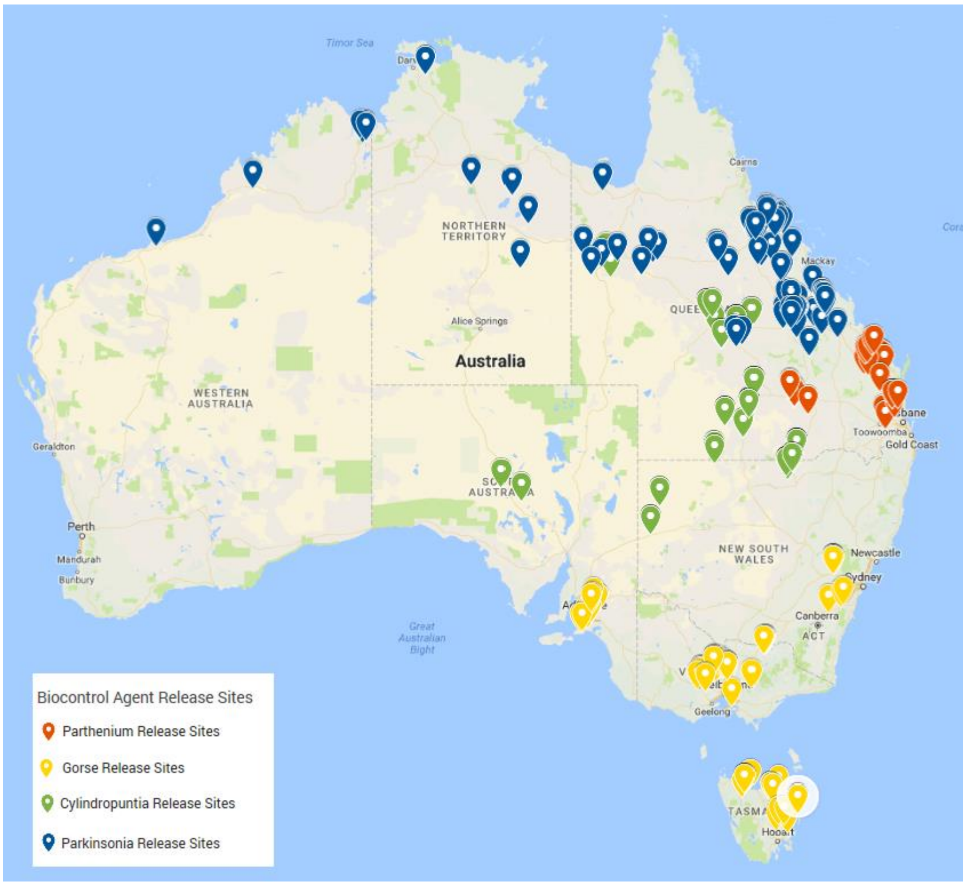
The Cylindropuntia sub-project achieved the mass rearing and redistribution of four biotypes of a sap-sucking bug or cochineal insect. Releases of these biotypes resulted in significant impact in less than twenty months, with mortality of the target weed observed. Work in this area also resulted in the development of a molecular diagnostic tool that identifies plants to the cultivar level.

The gorse sub-project resulted in the successful collection, mass rearing and redistribution of gorse soft shoot moth to 83 sites. Monitoring has shown a promising fungus has infected plants previously damaged by the moths and may become a significant factor in suppressing the spread of gorse in the future.

Two agents were reared and released at 100 sites to assist with the integrated management of parkinsonia. The insects established at more than 50% of the sites and spread considerable distances on their own, indicating they are likely to find and attack parkinsonia plants across the rangelands. This work has also improved the efficiency of mass-rearing processes, and identified optimal locations for releases in Australia, which will improve survival and establishment rates and associated weed impacts.

The project expanded previous investment and releases of agents on parthenium. All but one of these agents have established across central Queensland with most agents causing substantial damage to, and control of, parthenium. This work also helped to train more than 36 community group members in the rearing and field release of various parthenium biological control agents.

In addition to delivering higher than expected numbers of control agents across vast tracts of northern and southern Australia (nine agents on five weeds across more than 270 sites – Figure 4), the Australian Biocontrol Hub ensures the legacy of knowledge gained through historical, current and



future biocontrol activities remains up-to-date and accessible beyond the life of any given project: https://biocollect.ala.org.au/biocontrolhub

The failure of prospective agents for two weeds (silverleaf nightshade and blackberry) was identified through the host-specificity testing process. While a setback for the biological control of these particular weeds, the rigorous process of testing agents on a diverse range of plants and consultation with potentially impacted stakeholders is vital in maintaining broad community support for biological control options, and is equally applicable to both pest plants and animals.

A shared investment funding model has been piloted in NSW. The model has effectively laid the foundations for maximising the delivery of multiple biocontrol agents on the ground, while fostering a more sustainable and collaborative user-pays model for biocontrol services for the future than any other model developed in Australia.

A cost–benefit analysis (CBA), undertaken as part of the project, has estimated the value of total benefits at $13.91 million (present value terms) and an estimated net present value (NPV) of $9.44 million – a benefit–cost ratio (BCR) of approximately 3.1 to 1, an internal rate of return of 16% and a modified internal rate of return of 9%.

Conclusions and recommendations

In some weeds, impact at scale from biological control agents can require 30 years and for other weeds the time to impact is much shorter. The *Fast-tracking* project has demonstrated that human intervention in weed biocontrol systems, supported by a dynamic and collective knowledge base and innovative technologies, can, through a collaborative and consultative approach, hasten the impact and scale of biocontrol efforts. The collaborative efforts from organisations working alongside the

Figure 4. Biocontrol agent release sites across Australia for the *Fast-tracking* project.

core sub-project teams was critical to achieving impact at scale over a relatively short timeframe – this type of impact is not practical or feasible without this level of collaboration.

For primary producers, the collective impact of the cumulative achievements across the *Fast-tracking* project is: greater engagement with, and improved access to, best-practice weed management information and technology, a superior range of biocontrol agents, and enhanced confidence in the biocontrol RD&E pipeline, which will deliver faster impacts at landscape scale. With this collective impact will come associated increases in profitability through higher productivity and lower costs.

The ability to identify, rear and release a multitude of agents, each acting on different parts of the plant and across seasons, also will increase impact. To that end research to facilitate an efficient and time-effective discovery-to-delivery pipeline, supported by consultative and collaborative processes, has the greatest opportunity for cumulative success. That is, a coordinated approach at scale is critical to success and maximising efficiency of resource use.

This type of research process – a coordinated and expanded R to E pipeline – is recommended as a future model; not an exception, rather the norm to enable future impact at scale. Combined with a developing knowledge of rate of spread of agents, greater precision can be added into the future planning (where/when to release) in concert with a dispersed deliverers' network to ensure success.

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Abbreviations and acronyms

ALA	Atlas of Living Australia
AMLR NRM	Adelaide Mounty Lofty Ranges Natural Resource Management
BCR	Benefit–cost ratio
CBA	Cost–benefit analysis
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAFWA	Department of Agriculture and Food, Western Australia
DEDTJR	Department of Economic Development, Jobs, Transport and Resources (Agriculture Victoria)
DENR	Department of Environment and Natural Resources (Northern Territory)
DAWR	Australian Government Department of Agriculture and Water Resources
GSSM	Gorse soft shoot moth
MLA	Meat & Livestock Australia
NCRIS	National Collaborative Research Infrastructure Strategy
NPV	Net present value
NRM	Natural resource management
NSW	New South Wales
NSW DPI	New South Wales Department of Primary Industries
NSW LLS	New South Wales Local Land Services
NT	Northern Territory
PIRSA	Primary Industries and Regions South Australia
QDAF	Department of Agriculture and Fisheries (Queensland)
RD&E	Research, development and extension
RDE&A	Research, development, extension and adoption
ROI	Return on investment
SA	South Australia
SLN	Silverleaf nightshade
SLNLB	Silverleaf nightshade leaf beetle
USA	United States of America
WA	Western Australia
WoNS	Weeds of National Significance

1 Project rationale and objectives

Widespread weeds cost Australian agriculture more than $4.5 billion a year. The significant cost to livestock production, in particular, occurs via several concurrent processes including: reduced forage production, livestock product damage (meat and hides), animal health (toxins and physical injury), forgone and lost production, and the direct costs of control. Improved weed management on commercially productive land would facilitate:

- significant improvements in productivity (increased product per hectare)
- significant improvements in profitability (reduced costs).

The geographic spread of many of the serious weeds affecting livestock industries across vast tracts of Australia make chemical or mechanical weed control cost prohibitive. Biological control (biocontrol) is the only realistic option for managing many of these weeds.

History has shown biocontrol is the most cost-effective, self-sustaining weed management technology currently available. The collective national return on biocontrol program investment by 2006 was at least 23:1, which is unparalleled by any other widespread weed management method (Page and Lacey 2006). Biocontrol processes are continually and rigorously refined to maximise this return on investment (ROI) and minimise any off-target impacts. This scientifically rigorous approach applies proven, internationally accepted scientific principles for biocontrol agent discovery, rearing, risk assessment, field release, integration with farming systems and monitoring of effectiveness.

Biocontrol remains a national research, development and extension (RD&E) priority under the Australian Weeds Strategy and within endorsed national strategic plans for each of the Weeds of National Significance (WoNS) targeted in this project. Its application is independently regulated by the Australian Government.

A common limiting factor influencing the success of biocontrol programs worldwide is inconsistent and sporadic cycles of resources, such as boom and bust funding, which have significant impacts on capacity, scale and continuity of RD&E efforts. This issue is a major impediment to weed biocontrol capability across Australia, which in recent years has jeopardised Australia's reputation as being at the forefront in biocontrol (Palmer et al. 2014). When capacity, scale and partnerships are lost they are extremely difficult to regain. Without implementation of biocontrol at a large scale the benefits take much longer to be realised. With many weeds, impact from agents could be at least 30+ years without large-scale effort.

The *Fast-tracking and maximising the long-lasting benefits of weed biological control for farm productivity* project (*Fast-tracking* project):

- conducted research and delivery on six national priority agricultural weeds (parkinsonia, parthenium, blackberry, silverleaf nightshade, *Cylindropuntia* spp. and gorse) and associated biocontrol agents
- aimed to improve the efficiency of information generation (via partnerships in research, delivery and funding) and information exchange (via Australian Biocontrol Hub and smartphone app).

The combination of the above efforts was central to addressing current deficiencies in the weed biocontrol pipeline and will greatly assist the likely future impact on weed infestations.

About the six target national priority weeds

In addition to being WoNS, the weeds targeted in the *Fast-tracking* project were selected based on two recent scientific reviews commissioned by Meat & Livestock Australia (MLA), which identified the weeds of greatest impact on the Australian grazing industry for which biocontrol has the highest likelihood of success.

Blackberry – European blackberry refers to a group of plants within the *Rubus fruticosus* family that are insidious invaders of southern Australian pastures and natural ecosystems where annual rainfall exceeds 700mm. During 2006, annual loss of production and cost of control relating to blackberry in agriculture was estimated to be between $95.1 million and $102.8 million. The search for a biocontrol solution for blackberry started during the 1970s, with extensive field surveys across Europe, the native range. Only one biocontrol agent, the leaf-rust fungus *Phragmidium violaceum*, which does not pose a risk to cultivated brambleberries and native Rubus species, has been introduced in Australia.

Cylindropuntia – *Cylindropuntia* spp. are members of the cactus family and originate from the southern United States of America (USA), Mexico, Chile, Ecuador and the Caribbean island of Hispaniola. Eight *Cylindropuntia* spp. are recorded as weeds in Australia. They cause agricultural, environmental and recreational problems through direct injury from their spines and competition with desirable plant species. Substantial parts of arid and semi-arid Australia are at risk of invasion by *Cylindropuntia* spp.

Gorse – *Ulex europaeus* L. is a WoNS and one of the most invasive weeds in south-eastern Australia. The annual cost of gorse management to Australian agricultural and forest industries during 2000 was estimated at $7 million.

Parthenium – *Parthenium hysterophorus L.* (Asteraceae) is a noxious weed of grazing areas across Queensland and a WoNS. The weed was estimated to reduce grazing land and pasture production by more than $16.5 million annually across 170,000km^2 during 1991. Currently the weed infests more than 360,000km^2 across Queensland. Biocontrol is the most cost-effective, long-term management option for this invasive weed. Biological control of parthenium in Australia was first initiated during the late 1970s.

Parkinsonia – *Parkinsonia aculeate* is a shrub/tree species introduced to Australia as an ornamental species and for its potential value as a hedging and fodder plant. It has since spread to occupy more than 8000km^2 of the rangelands of northern Australia, and forms dense thickets across floodplains and grasslands, along watercourses and bore drains. Parkinsonia impacts the pastoral industry and rangeland production systems by limiting pasture growth, restricting stock access to water and impeding mustering efforts.

Silverleaf nightshade (SLN) – *Solanum elaeagnifolium* Cav. is a deep-rooted invasive perennial weed, which reduces productivity and profitability across the wheat–sheep agricultural zone of Australia. It infests more than one million hectares across Australia and costs farmers $70 million every year. Biological control is the most likely long-term solution.

The targeted weeds all have a high propensity for spread and a broad adaptation zone they may colonise.

Figure 5. Parkinsonia.

1.1 Project objectives

The over-arching project aimed to fast-track biological weed control to improve agricultural production and deliver a benefit to the Australian economy through increased profitability.

Through the eight interlinked sub-projects, the *Fast-tracking* project aimed to:

a) greatly increase the on-farm populations of eight weed biocontrol agents

b) reduce weed competition and herbicide use across more than 25 million hectares

c) reduce the densities of the six target weeds across northern and southern Australia

d) increase long-term annual yield and reduce annual weed control costs

e) improve agricultural natural resource management nationally

f) inform producers of weed management options

g) establish a new collaborative national approach to weed biocontrol.

Biological control of weeds is not an instant solution. Realising a reduction in weed density and seeing an improvement in agricultural production is a long-term outcome of biocontrol endeavours, in combination with other weed management tools.

However, consistent with the broad-reaching objectives of the Rural R&D for Profit program, the achievements of the *Fast-tracking* project build on lessons learned through the various successes and pitfalls of historical approaches to weed RD&E to ensure the outputs of the suite of sub-projects will persist and grow long after the projects themselves have ceased.

2 Method and project locations

Project methodology

To achieve the Rural R&D for Profit program objectives, benefits for weed management and the sub-project outputs, the *Fast-tracking* project sought to build producer–researcher–investor communities of practice in weed biocontrol. This consisted of the formation of partnerships, information and product exchanges along the RD&E pipeline, seeking to address fragmentation and redeveloping a critical mass of effort.

The principles guiding each sub-project were to:

- employ effective project implementation, ensuring coordination and cooperation between the sub-project research and delivery areas, and information exchanges between project participants, stakeholders and other weed managers
- investigate and develop an innovative partnership model which monitors and maintains a functional and ongoing biocontrol agent delivery pipeline, well beyond the life of the project
- accelerate host-specificity testing by developing and employing new methods and technologies for assessing candidate biocontrol agents
- build efficiencies in mass rearing, redistribution and field impact assessment processes through novel approaches and protocols that are transferable to producers and other land managers
- develop and extend best practice management for biocontrol agents through the Australian Biocontrol Hub and accompanying smartphone app (including agent identification, establishing nursery sites and agent management, in association with grazing and herbicide use)
- address the project *modus operandi* by designing the most efficient experimental and delivery approaches through consultation of the scientific literature and between R&D providers and jurisdictions involved in weed management and information delivery to landholders.

As the weeds targeted under the *Fast-tracking* project (and its component sub-projects) are located across seven states and territories, numerous jurisdictions were involved in the research-to-delivery pipeline. Collaboration and coordination was critical to the *Fast-tracking* project's success. As such, the project harnessed the contributions and participation of many organisations. More than 120 organisations participated in the project in some way. In addition, many private landholders and land managers also collaborated with the project.

Location and impact of project activities

As a collection of interlinked sub-projects, project teams across multiple states and organisations managed and carried out the activities under the *Fast-tracking* project. The locations and impacts of individual sub-project findings are covered on the following pages. More detail about individual sub-project activities and methodologies can be found in Appendix 7.6.

Through collaboration with weed management stakeholders, the *Fast-tracking* project achieved releases of nine biocontrol agents for four WoNS across more than 270 sites across northern and southern Australia (Figure 6).

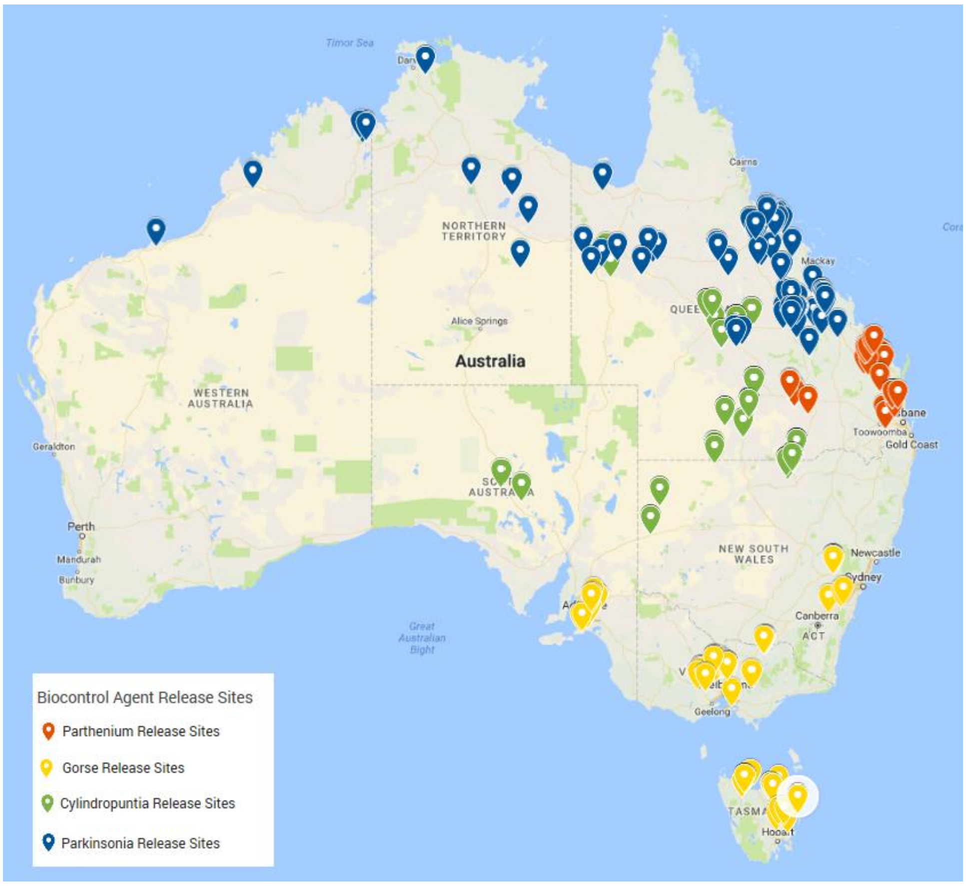

Figure 6. Biocontrol agent release sites across Australia for the *Fast-tracking* project.

Partnership model

The partnership model was managed by a team from New South Wales Department of Primary Industries (NSW DPI) with support from MLA, based in NSW.

The team consulted with weed management stakeholders (agencies, local government etc.) across NSW and Queensland, and reviewed an international model in New Zealand, to develop a shared investment framework as a basis for an ongoing sustainable model for funding and partnerships. Preliminary consultation and discussion with local and state government, NSW Local Land Services (LLS) and other interested parties was carried out to determine feasibility for shared investment and a suitable model for NSW, with the potential to expand to other states and territories.

Blackberry

The Blackberry biological control project was led by CSIRO and supported by teams from Murdoch University, Western Australia (WA), Agriculture Victoria, NSW LLS (Murray) and MLA. The project primarily focused on determining if the blackberry decline syndrome, observed in south-west WA during the past 10 years, could be manipulated and developed as an effective and safe biocontrol tool.

Initial blackberry experiments, conducted using isolates of *Phytopthora bilorbang* from Murdoch University, proved inconclusive. Additional blackberry samples – from sites where the decline has been observed in WA – were then collected and processed to recover new isolates. Two dominant species were recovered – *P. bilorbang* and *P. pseudocryptogea*.

A new experiment with a revised methodology* was performed using isolates of both species. *Phytophthora pseudocryptogea* became the focus of subsequent research. In host-specificity tests, *P. pseudocryptogea* did not significantly affect pasture species, but killed or considerably reduced growth of several native species in the Acacia, Callistemon and Eucalyptus genera. These results were the basis for the decision not to proceed with field trials and instead undertake preliminary investigations of an alternative agent – a stem-boring sawfly.

***Note:** This project development represents the only change to the methods prescribed in any of the contracted sub-projects under the *Fast-tracking* project. Since Phytophthora species were found not to be a viable option for blackberry biocontrol, the project undertook a preliminary investigation, which is still ongoing, into the stem-boring sawfly *Phylloecus faunus (=Hartigia albomaculata)*, identified in the 1970s in Europe, as a potential biocontrol agent for blackberry.

The project has outlined a range of possible options as the next steps towards blackberry biocontrol in Australia.

Cylindropuntia

The Cylindropuntia biological control project was led by NSW DPI, in conjunction with Queensland Department of Agriculture and Fisheries (QDAF) and supported by MLA.

Substantial parts of arid and semi-arid Australia are at risk of invasion by *Cylindropuntia* spp. Biocontrol of cactus species has been highly successful, with the control of prickly pear and several other species.

Cylindropuntia spp. have been targeted for biocontrol with the release of a sap-sucking bug or cochineal insect, *Dactylopius tomentosus*, first released in Australia during 1925 to control rope pear (*C. imbricata*). This biotype, has been successful in controlling rope pear species in Australia, but it does not affect the other seven invasive *Cylindropuntia* spp. Biotypes are populations of the same insect species that can only be separated by their different abilities to feed, lay eggs and develop on a target species.

Populations of *D. tomentosus,* previously imported into Australian quarantine, were evaluated for host-range and impact testing with the aim of identifying biotypes with the potential to target the remaining uncontrolled *Cylindropuntia* spp. in Australia. As a result of the testing process seven biotypes of *D. tomentosus* were found suitable for release. Prospective control agents underwent mass rearing in NSW (Orange) and Queensland (Brisbane) and were released across NSW and Queensland (see Figure 4). Laboratory rearing colonies (pure strains) of the cholla biotype (from South Africa) are maintained in Orange and Brisbane. In addition, rearing colonies have been established at Mt Isa, Longreach, Charleville (QLD), SA and WA. Laboratory rearing colonies of the *californica var. parkeri* biotype have been established and are maintained in Orange and Brisbane. Field rearing colonies have been established at Cumborah and Lightning Ridge (NSW). Laboratory rearing colonies of the *bigelovii* and *Cylindropuntia* spp. biotypes have been established in Brisbane.

A molecular diagnostic tool developed during the project to assist with identifying *Cylindropuntia* spp., and so facilitate alignment of *Cylindropuntia* spp. and agent, will allow the findings of this project to have potential impact across all areas suffering *Cylindropuntia* spp. infestations. This includes inland and sub-coastal regions of southern Queensland, NSW, north-western Victoria, south-eastern South Australia and the NT.

Gorse

The biological control of gorse project was led by Agriculture Victoria. Additional project partners included:

- Connecting Country
- Ovens Landcare Network
- Tasweed Biocontrol
- Victorian Gorse Task Force
- South West Goulburn Landcare
- South Australia Murray Darling Basin NRM
- Adelaide Mount Lofty Ranges NRM
- NSW DPI
- Department of Environment, Land, Water and Planning (Victoria) and Central Highlands Eden Project partner agencies
- University of Melbourne.

The difficulty and expense in controlling gorse by conventional means has resulted in the investigation and implementation of biocontrol options. The gorse soft shoot moth (GSSM) has shown considerable promise in Tasmania, however, prior to this project, releases of GSSM on mainland states were limited, and the few small populations were vulnerable to extinction.

Surveys were carried out at 25 previous release sites in Tasmania to determine viable populations. At sites where populations were established, GSSM was collected for redistribution at more than 20 new sites across gorse-infested regions of Victoria and at least two new sites in South Australia (SA) (Figure 4).

Moth collection field days were held in Tasmania at field sites where the moth could be harvested in large numbers for redistribution to the mainland. Field activities were organised locally and involved collaborators from Victoria, NSW and SA. Moth release and monitoring field days were held in Victoria and SA to support successful establishment and dispersal. The research findings are applicable across NSW, Victoria, Tasmania and SA.

Parkinsonia

The biological control of parkinsonia project was led by CSIRO (Brisbane) in conjunction with QDAF and supported by MLA. Other key partners include the former Department of Agriculture and Food WA (DAFWA), Pilbara Mesquite Management Group, Rangelands Natural Resource Management

(NRM) WA and the Northern Territory (NT) Department of Environment and Natural Resources (DENR).

During 2012 and 2014 CSIRO received approval to release two closely related leaf-feeding moths, *Eueupithecia cisplatensis* and *Eueupithecia vollonoides* (nicknamed UU1 and UU2 respectively).

Building on earlier work on these species, this project developed a detailed understanding of the development of UU1 and UU2 in relation to variations in temperature. The project team undertook bioclimatic modelling to determine where, across parkinsonia's infestation in Australia, each species is likely to perform best.

Significant numbers of each species were mass reared and released at parkinsonia-infested sites across Queensland, NT and WA. The sub-project team and collaborators monitored establishment of these agents across northern Australia. The team also worked with a vast network of regional stakeholders across Queensland, NT and WA to improve awareness of the value of biological control within an integrated management approach for parkinsonia and other rangelands weeds.

The area across northern Australia that parkinsonia could potentially spread across has been mapped and reported in the sub project report.

Parthenium

The biological control of parthenium project was led by QDAF and supported by MLA. Several community organisations such as Queensland Murray Darling Committee, Maranoa Landcare, Junction View Pest Management Group, Oxley Catchment Group, Healthy Land and Water, North Burnett Regional Council, Bundaberg Regional Council and landholders actively participated in the rearing and release program.

Biological control of parthenium in Australia was first initiated during the late 1970s. Eleven agents have since been released in core parthenium-infested areas of central and northern Queensland. All but one of these agents have established in central Queensland, with most causing substantial damage to and control of parthenium, although effectiveness of the agents varies seasonally.

This project provided the opportunity to collect, rear and redistribute these agents to new locations, hastening natural spread and adding to the range of agents that can impact the plant, overcoming deficiencies in current agents (e.g. seasonal conditions not favouring reproduction of a leaf rust).

In consultation with local Landcare and community groups, local governments, regional councils, graziers and stakeholders, field collection of existing agents was carried out across 19 sites in central Queensland. The sub-project released and established five biological control agents both from field collections and glasshouse cultures across 30 sites in south and south-east Queensland.

Silverleaf nightshade (SLN)

The biological control of silverleaf nightshade project was led by Primary Industries and Regions SA (PIRSA) and supported by MLA, Department of Environment and Water SA, Agriculture Victoria and NSW DPI.

This project aimed to import the silverleaf nightshade leaf beetle (*Leptinotarsa texana*; SLNLB) – a highly successful biocontrol agent for SLN in South Africa – under quarantine, and assess its suitability as a biological control agent for SLN in Australia.

A total of 152 SLNLB were imported from South Africa to Melbourne under quarantine laboratory conditions during April 2016 and a rearing colony was developed.

A molecular tool was used to identify the beetles and ensure DNA from the beetles differed significantly from SLNLB's relative and potato pest – the Colorado potato beetle.

In extensive consultation with industry stakeholders, the SLNLB was offered a wide range of native plants and crops closely related to SLN.

Extensive field collection trips were conducted to collect seed and cuttings across SA and NSW, with samples provided from the NT, WA and Queensland. Horticultural varieties were obtained from commercial nurseries. A total of 654 test plants were collected. This collection of propagation material of wild species is a major output of the project.

Unfortunately, the SLNLB fed on 15 native plants as well as eggplant. During late 2017 it also attacked a group of related potato varieties, something not recorded by the South African researchers.

The research team immediately ruled out SLNLB as suitable for release in Australia. Additional field experiments with susceptible potato cultivars are currently underway in Texas.

Biocontrol Hub and app

The biocontrol portal and app project was led by Agriculture Victoria, supported by MLA and partnered with the Atlas of Living Australia (ALA).

Information about biological control and all aspects along the discovery-to-delivery pipeline has historically been difficult to access, collate and maintain. Information is often incomplete and resides in numerous repositories managed by disconnected organisations.

The project has developed and road tested a one-stop-shop repository for current weed biocontrol knowledge and information, housed on the ALA website.

Smartphone application (app) beta testing was carried out with project partners (NSW, Tasmania, Victoria and Queensland), private consultants (Tasmania and Victoria), NRM/Landcare collaborators (SA and Victoria) and selected producers (Tasmania and Victoria). The app was demonstrated to 220 stakeholders (including producers) at agent release sites in Queensland, NSW, Victoria, Tasmania and SA, including at least eight field days in Victoria and Tasmania.

The app has been promoted through project partner websites and social media, project stakeholder forums and project-related media releases.

This project has provided a mechanism whereby land managers have ready access to current knowledge on weeds that have been targeted for biocontrol, where and how to obtain biocontrol agents for their region, and how to integrate them with weed management activities at the property, local and regional scale.

The new Australian Biocontrol Hub, combined with smartphone technology and a custom-made app, has potential to transform the sustainable management of weeds in Australia.

The Australian Biocontrol Hub and app are available through ALA: https://biocollect.ala.org.au/biocontrolhub

Figure 7. Neale Jensen (North Burnett Regional Council) finding Smicronyx at Mundubbera release site, November 2017. Photo courtesy QDAF

3 Overall project achievements

The over-arching *Fast-tracking* project (comprising the eight interlinked sub-projects) successfully delivered against the contracted outputs. Underpinning these outputs, the sub-projects aimed to respond to a range of higher-level questions to ensure short-term success (e.g. delivering a suite of new control agents that are fit for purpose), while delivering to the longer-term timeframe of biological weed control and maintaining broader community confidence in discovery-to-delivery pipeline processes and protocols.

The higher-level questions the sub-projects collectively responded to include the following:

- How can we maximise agent spread and weed suppression through strategic redistribution, and effectively and efficiently evaluate the benefits of weed biocontrol at a landscape scale?
- What tools can we develop to better understand the genetic origins of a target weed to determine weed relatedness and fast-track a match between weed targets and biocontrol agents? (Note: Work was pioneered by Australian researchers and new technologies were applied in the Cylindropuntia and silverleaf nightshade sub-projects.)
- How can we select the most specific and effective agents to control target weeds to optimise control in the shortest timeframe?
- How can we refine biocontrol agent risk assessment to minimise effort and risk?
- How do we ensure successful mass rearing, release and establishment of each new biocontrol agent into the Australian environment at the lowest cost?

A unique ecological solution was required in each case, optimised by experience and experiments, and addressed in weed-specific sub-projects of blackberry, silverleaf nightshade, parkinsonia, parthenium, *Cylindropuntia* spp. and gorse.

As part of the project evaluation process, a survey was completed by 86 project stakeholders. The project achievements outlined below combine some of the responses from this survey, along with other evidence. Further details of the survey can be found in Appendix 7.4.3.

The Rural R&D for Profit program's *Fast-tracking* project achieved the following as a whole:

- Collaborations – worked with more than 120 organisations and more than 200 land managers
    - 85% of survey participants said the project had provided a better process to deliver collaborations than the previous decade
    - 95% of survey participants said their involvement in the project had been personally rewarding, compared with other projects
    - 49 community group members were trained in rearing and field release skills across parthenium and parkinsonia agents
    - New networks and partnerships were developed in the RD&E pipeline for five weeds – silverleaf nightshade, parkinsonia, parthenium, Cylindropuntia and gorse

    - Consultation was carried out with key stakeholders potentially impacted by biocontrol options.

- Improving the RD&E pipeline – protocols/testing/procedures
    - Efforts were focused on biological control options and delivery for six weeds across seven states
    - Two molecular approaches developed, improving weed identity and so host testing
    - All sub-projects followed rigorous testing and release protocols to ensure public confidence in the biocontrol RD&E pipeline. Achievements in this space were borne out not only by the successful release of nine agents on five weeds across more than 270 sites, but also the failure of two agents to reach the release stage (see Note below).

- Improving business practices
    - 75% of organisations surveyed stated they had been able to access technical skills not previously available
    - 85% of survey respondents said their involvement in the project increased their skills and knowledge
    - 85% of survey respondents said the project had provided a better process to deliver collaborations than the previous decade
    - Accelerated scale and speed of biocontrol agent release and impact through collaboration and business practices: Releasing and, importantly, redistribution of agents is a key to fast-tracking success. Traditionally, releases are made at limited sites, based on the available funds and networks within a project. This is generally followed by slow increase and spread of agents, with potential negative seasonal impacts decreasing populations. The *Fast-tracking* project has hastened that spread through large-scale human support in collecting and moving agents to new locations and by utilising new stakeholders in those regions.

Brief examples of the *Fast-tracking* project contributions to the overall national benefit are outlined below:

a) Greatly increase the on-farm populations of eight weed biocontrol agents:
    - Contribution: The rearing and release of biocontrol agents at scale (i.e. delivering agents to more than 270 new sites across Australia).

b) Reduce weed competition and herbicide use across more than 25 million hectares:
    - Contribution: Post-release monitoring of infestations of parkinsonia, gorse and parthenium indicated biocontrol agents had significantly weakened the weed populations.
    - Contribution: Death of Cylindropuntia plants due to the release of agents.

c) Reduce the densities of the six target weeds across northern and southern Australia:
    - Contribution: Four target weeds impacted by agents (parkinsonia, *Cylindropuntia* spp., gorse and parthenium) demonstrated through site monitoring.

d) Increase long-term annual yield and reduce annual weed control costs:

- Contribution: Decreased weed competition, from weakened or dead weeds, allows more desirable pasture species to flourish and reduces the need for (and expenditure on) alternative weed control.

- Contribution: The legacy of new knowledge and processes will support related initiatives towards long-term annual yield improvements.

e) Improve agricultural natural resource management nationally:

- Contribution: New biocontrol agents, improved knowledge, understanding and processes, combined with expanded capacity through new and enhanced partnerships, will boost national resource management nationally.

- Contribution: Greater adoption and impact of biocontrol agents as part of an integrated weed management program will reduce the reliance on resource-heavy and environmentally compromising tools, such as mechanical and chemical control.

f) Inform producers of weed management options:

- Contribution: The project informed producers through 41 field days and trained 236 individuals in various aspects of biocontrol agent distribution and monitoring (many of whom were producers).
- Contribution: In addition to multiple extension products, the Australian Biocontrol Hub and smartphone application have delivered a legacy product for the collation of historical, current and future information and a source of interactive information collection and delivery.

g) Establish a new collaborative national approach to weed biocontrol:

- Contribution: 120 organisations with a responsibility in weed management across the RD&E pipeline worked together to achieve the project outputs.
- Contribution: 42 organisations indicated the project has provided a better process to deliver collaborations than in the previous decade.
- Contribution: 54 organisations indicated the collaborative approach of the project has significantly improved their access to new networks and contacts.
- Contribution: 41 organisations indicated the collaborative approach of the project has significantly improved their access to technical skills that were not available previously.
- Contribution: An alternative, feasible funding partnership model was piloted in NSW, across multiple weed management jurisdictions.

Note: The failure of prospective agents for two weeds (silverleaf nightshade and blackberry) was identified through the host-specificity testing process. While a setback for the biological control of these particular weeds, the rigorous process of testing agents on a diverse range of plants, and consultation with potentially impacted stakeholders is critical to maintaining broad community support for biological control options, and is equally applicable to both pest plants and animals.

Matching agents to target weeds is costly and the risk of failure is always looming. Importantly the *Fast-tracking* project developed testing approaches to reduce this risk through the use of molecular tools, which can be used to:

- ensure the Australian weed is of the same genetic background as the native weed (i.e. where the candidate agent is sourced)
- assess other plants in the same genetic family as the target weed (i.e. to determine which plants should be included in host-specificity testing). For example, eggplant, potato and tomato are from the same genetic family as silverleaf nightshade.

Success at field release sites has been documented with the establishment of agents. As such, field collection and redistribution has become possible for weeds such as *Cylindropuntia* spp., gorse, parthenium and parkinsonia.

A key lesson, for broader application of the component projects, is that knowledge of establishment and rate of spread can underpin estimations of the time to impact at scale and how human intervention can hasten this benefit (i.e. release site location, number of re-releases required etc.)

Vastly improved interactions and relationships among researchers, land managers and other stakeholders, developed through the life of the project, provide a secure platform to enable biological control to achieve impact at scale into the future. The consultative approach taken across the sub-projects (e.g. with respect to sampling for host-specificity testing) demonstrates that while biocontrol researchers are keenly aware of the benefits of a biological approach to weed control, they are also well aware of, and go to lengths to avoid, the implications of off-target damage. The molecular studies, recognition of potential off-target impacts, consultation and agent identification for future work has a sound basis in the approaches and achievements of this project.

The collaborations and new networks formed during the project have enabled the delivery of the project outputs. There is also evidence these new networks will be an ongoing legacy of the project. In the case of parkinsonia, delivery of agents across three northern states was achieved through collaborations between researchers, extension officers, biosecurity officers and stakeholders across Queensland, NT and WA. This close collaboration, across more than two dozen agencies and stakeholder groups, is being extended through work on other weeds beyond the life of this project through a related Rural R&D for Profit program.

The stakeholder survey undertaken indicates the project has significantly increased awareness of biological weed control options among stakeholders, and provided new networks and knowledge. Importantly, survey respondents reported an improvement in the implementation model compared with that of the past decade.

A cost–benefit analysis (CBA), undertaken as part of the project, has estimated the value of total benefits at $13.91 million (present value terms) and an estimated net present value (NPV) of $9.44 million – a benefit–cost ratio (BCR) of approximately 3.1 to 1, an internal rate of return of 16% and a modified internal rate of return of 9%. More details on the CBA can found in Appendix 7.4.2.

A summary of the specific sub-project achievements follows. Greater detail against contracted outputs can be found in Section 3.1 and sub-project reports can be found in Appendix 7.6.1–7.6.8.

Partnership model

A shared investment funding model has been piloted in NSW. The model has effectively laid the foundations for maximising the delivery of multiple biocontrol agents on the ground, while fostering a more sustainable and collaborative user-pays model for biocontrol services for the future than any other model developed in Australia.

Following preliminary consultation, a conceptual model was developed for NSW based on the experience of a well-established and successful program run by the National Biocontrol Collective of New Zealand, and a local (north coast) test case led by the NSW Weed Biological Control Taskforce (NSW Taskforce). The NSW Taskforce is undertaking a long-term commitment to the new partnership model developed by the project team. The Taskforce Terms of Reference (ToR) have now been revised to incorporate their commitment to the model. A prospectus has been developed for stakeholder engagement and subscription.

Due to Queensland being already committed to an existing levy-based funding model, the project team was advised there was no impetus for current change in Queensland at this point in time.

The outcome in developing this model was to obtain financial backing from federal and state governments, NSW LLS, local government and other stakeholders to form a centralised RD&E node led by the NSW Taskforce. Collectively this node brings together Australia's leading RD&E agencies to fast-track and maximise the on-ground delivery pipeline of biological control agents.

The model was developed from a NSW-centric position (i.e. structures operating in that state) and the portability of the model nationally is not guaranteed. Notwithstanding this, the principles are portable and consist of:

- beneficiaries pay
- participation by multiple stakeholders at multiple levels (federal/state/local jurisdictions)
- information exchange and priority setting by participants
- level of cash contribution (in light of an investment prospectus describing the benefit) relates to delivered benefits.

Blackberry

The project primarily focused on determining if the blackberry decline syndrome, observed in south-west WA during the past 10 years, could be manipulated and developed as an effective and safe biocontrol tool.

In host-specificity tests, the prospective pathogen *P. pseudocryptogea* did not significantly affect pasture species, but killed or considerably reduced growth of several native species in the Acacia, Callistemon and Eucalyptus genera.

These results were the basis for the decision not to proceed with field trials. The project has outlined a range of possible options as the next steps towards blackberry biocontrol in Australia.

Cylindropuntia

The Cylindropuntia project has achieved the mass rearing and redistribution of four biotypes of a sap-sucking bug or cochineal insect, *D. tomentosus,* across NSW and Queensland and development of a molecular diagnostic tool that identifies plants to the cultivar level.

Releases of cochineal biotypes were successful in less than 20 months at Longreach and Hebel sites, with mortality of the target weed observed at both sites.

Mass rearing and release

Between November 2016 and April 2018, 849 infected *D. tomentosus* cholla biotypes were released at 36 sites across Queensland, NSW, WA and SA. Establishment was confirmed at 16 of these sites, with the remaining 20 release sites not checked (due to their remoteness).

Infected biotypes have been supplied to 11 councils (NSW and Queensland), two NSW LLS branches (Western and North West) and two Queensland NRM groups (Desert Channels and Southern Gulf).

Establishment, spread and impact

Monitoring evaluated the establishment, rate and direction of spread, and impact of the agent on *C. fulgida* at Leander Station in central Queensland and Booligar Station in south-west Queensland. The rate of spread was consistent between the two monitoring sites. Nineteen months after initial release the cholla biotype showed significant impact. Newly emerged crawlers, which are windborne, were found to have spread distances of 220m (Leander Station) and 300m (Booligar Station) in the first year, in a predominantly south-westerly direction. Within 18 months, 100% of plants at the Leander Station monitoring site had been infested with the insect and 95% of these plants had been killed. At Booligar Station, 100% of plants had been infested with the insect and 83% had been killed. This result exceeded expectations, however, to facilitate this spread even further, land managers are being encouraged to manually spread infected cladodes (a flattened leaf-like stem) to plants 20m from the nearest infected plants.

Of the plants that managed to survive, many had been severely damaged by the insect and were showing signs of poor health. These results indicate a successful future for the biocontrol of *C. fulgida* var. *mamillata* in Australia.

Molecular studies

Molecular studies have reached the point where all eight *Cylindropuntia* spp. present in Australia can now be identified from their DNA. There are multiple benefits in adopting the molecular tool developed as a part of this project for species identification. First and most importantly, correct identification will lead to matching the most effective biotype to the target. Secondly, time-efficient confirmation allows rapid and appropriate response to new infestations. Thirdly, the *D.tomentosus* biotypes identified can interbreed and the progeny may display a difference in host range and host performance, which could result in a reduction of the virulence and impact on the target species. Correct identification will assist in reducing cross-contamination of the biotypes at an infestation site.

Previously, without a confirmed identification of the Cylindropuntia species being targeted, a series of host and feeding impact trials would be required to determine the most suitable biotype of *D. tomentosus*. These trials would take up to three months to complete.

Gorse

The gorse biological control project successfully collected, mass reared and redistributed gorse soft shoot moth (GSSM) to 83 sites across Victoria, Tasmania, NSW and SA.

More than 250,000 adult moths and larvae were recovered from 31 sites across Tasmania. The 19 sites where the agent has permanently established are now recorded on the Australian Biocontrol Hub.

Gorse soft shoot moth was introduced at 22 new sites across Victoria and 16 new sites in SA. Releases in SA were conducted as planned by Adelaide Mount Lofty Ranges (AMLR) NRM. South Australia Murray Darling Basin NRM and AMLR NRM conducted additional GSSM releases that were partly funded by other sources, but made possible through engagement with this project.

During the project, knowledge has been accumulated about the climatic factors that support (or discourage) moth establishment. Twenty-four new releases were conducted in Tasmania to address distribution gaps in that state. The GSSM is unlikely to establish in wetter inland regions of north-west Tasmania where the average annual rainfall is approximately 1500mm.

Parkinsonia

Two biological control agents *Eueupithecia cisplatensis* and *Eueupithecia vollonoides* (nicknamed UU1 and UU2 respectively) previously approved for release in Australia were mass reared to provide sufficient quantities of agent to be released.

UU1 and UU2 were distributed at 100 rangelands sites across northern Australia (including Queensland, WA and the NT) to assist with the integrated management of parkinsonia.

Mass rearing hubs have been established for UU1 at Charters Towers and for UU2 in Brisbane. Rearing and widespread releases of agents were achieved through collaborations of CSIRO with key partnerships. Releases were supported by more than 100 regional co-operators, who released 275,000 moth larvae and pupae.

More than 200,000 UU1 (76 sites; 116 releases) and 75,000 UU2 (24 sites; 37 releases) were released on parkinsonia infestations. This is in addition to the 850,000 UU1 (112 sites; 324 releases) and more than 210,000 UU2 (19 sites; 56 releases) released as part of an earlier MLA-funded project.

Monitoring indicates the insects have established at more than 50% of the release sites and are starting to spread considerable distances (>10km) on their own. This spread indicates the agents are likely to effectively find and attack parkinsonia plants across the rangelands.

A physiological study of the heat tolerance of UU1 and UU2 has improved the efficiency of the mass-rearing processes, as well as identifying optimal locations for releases in Australia, which will improve survival and establishment rates and associated weed impacts.

New knowledge was developed across the life-history transitions of the agents to inform whether they are best released as pupae, juveniles or adults. Investigations into climatic modelling, heat tolerance and release age improve survival and likely weed impact of the agent.

Parthenium

This project expanded previous investment and releases of agents (the seed-feeding Smicronyx weevil, the root-boring Carmenta moth, the summer rust and the winter rust) on parthenium. All but one of these agents have established across central Queensland with most agents causing substantial damage to and control of parthenium, although effectiveness of the agents varies seasonally.

A total of 30 release sites were identified across southern Queensland in consultation with local Landcare and community groups, local governments, regional councils, graziers and other stakeholders. A total of 10 field collections were carried out at 19 sites across central Queensland and the collected agents redistributed across 20 sites in southern Queensland. These project activities provided an opportunity to mass rear and accelerate the redistribution of four agents across 20 sites in southern Queensland. Widespread establishment of many released agents has occurred after only two years.

The project also helped to train more than 36 community group members in the rearing and field release of various parthenium biological control agents.

Silverleaf nightshade

This project imported and established a quarantined breeding colony of a silverleaf nightshade beetle (*Leptinotarsa texana*).

Host-specificity testing indicated the beetle attacked *Solanaceae* species (genetic relatives of the weed) and so work on this agent discontinued. This demonstrated the rigour of the consultation and testing protocols utilised by the project and provides reassurance for the basis of sampling for host-specificity testing. It also provides greater confidence and reliability in selecting species in any future proposals.

There were three molecular biology (DNA analysis) tools developed within the project that have improved precision in aligning weed targets with suitable agents. The first investigated the geographic origins of silverleaf nightshade (SLN) introduced to Australia, and analysed silverleaf nightshade DNA from around the world to compare it with DNA of Australian SLN. The second component analysed the DNA of native Australian Solanum species to construct a phylogenetic model (family tree) based on molecular evidence, to best target relatives for host-specificity testing. A third component examined the DNA of imported *L. texana* beetles to confirm it was true to species.

The analysis of DNA from native Australian Solanum species samples covered almost 90% of the known Australian species. Research was also conducted into methods to germinate seeds of Australian Solanum plants, to improve the supply of test plants.

A major output from this project was a collection of propagation material of all wild species; now lodged with state-based herbariums.

Biocontrol Hub and app

A web-enabled platform providing access to current knowledge on weeds targeted for biocontrol and available agents, which is accessible in a single point for utilisation by the entire pipeline, was created during this project. Australian Biocontrol Hub and app available through ALA: https://biocollect.ala.org.au/biocontrolhub

The project uploaded content for 28 Australian weeds and 85 biocontrol agents and conducted beta testing with partners and collaborators and demonstrated and gained feedback from at least 200 producers and stakeholders across five states.

3.1 Sub-project level achievements

All eight sub-projects achieved their contract outputs. Sub-project activity was reported against a sub-project log frame, describing key activities and outputs. The outputs underpinned the contracted outputs. A collation and review of deliverables from the sub-project log frames (against Rural R&D for Profit program objectives) are reported in Appendix 7.4.1. All sub-project final reports are included in Appendix 7.6.1–7.6.8.

- Partnership model – outputs achieved
- Blackberry – outputs achieved

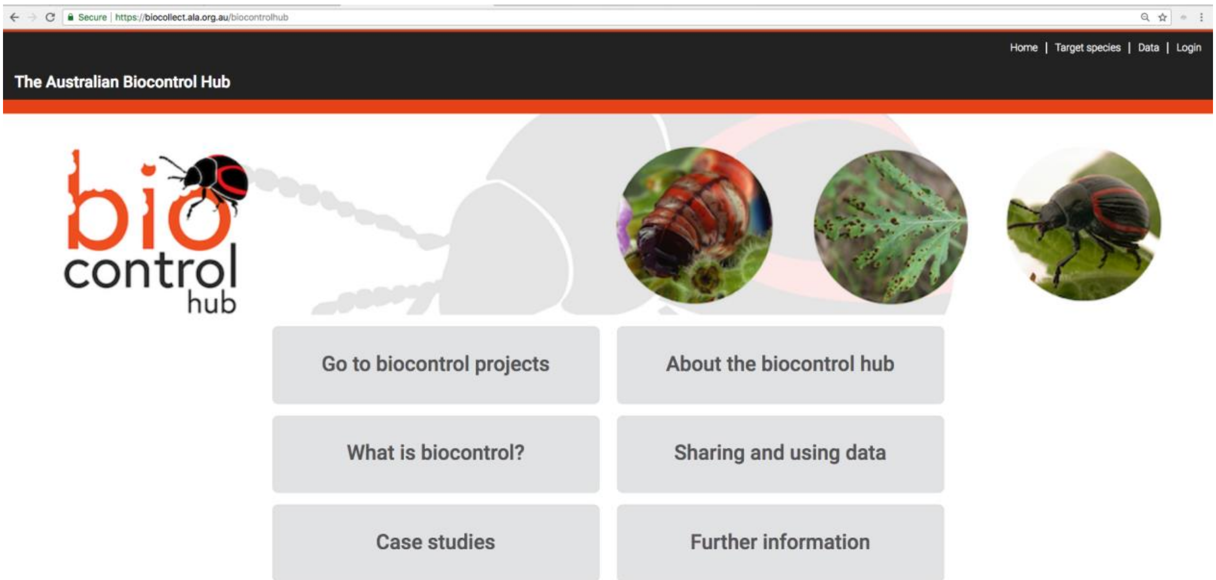

Figure 8. The Australian Biocontrol Hub, housed on the ALA, provides a legacy product which acts as a repository of research knowledge and information.

- Cylindropuntia – outputs achieved
- Gorse – outputs achieved
- Parkinsonia – outputs achieved
- Parthenium – outputs achieved
- Silverleaf nightshade – outputs achieved

- Australian Biocontrol Hub and app – outputs achieved

In addition to the contracted outputs a number of the sub-projects delivered additional non-contracted outputs. These have been summarised in Table 1.

Table 1. Summary of *Fast-tracking* project sub-project delivery and additional non-contracted outputs

Sub-project	**Summary status of delivery of contracted outputs (refer table below for component outputs)**	**Additional non-contracted outputs**
Partnership model	Met expectations	Not evident
Blackberry	Met expectations	Not evident
Cylindropuntia	Exceeded expectations	Releases at total of 44 sites (24 above target outputs). Establishment confirmed at 16 sites, release at 36 sites (*D. tomentosus* cholla biotype). Molecular studies – all eight species present in Australia can be identified by their DNA. Nineteen months after initial release on a point source plant at each site, the cholla biotype has had a significant impact.
Gorse	Exceeded expectations	Additional releases made in NSW and South Australia. Monitoring showed a promising fungus had infected plants previously damaged by moths.
Parthenium	Exceeded expectations	10 field collections were conducted at 19 sites. Agents released at 30 sites. The accelerated redistribution project has recorded unusual widespread establishment of many released agents after only two years. Trained 36 community group members in rearing and field release skills.
Parkinsonia	Exceeded expectations	Agents released at 100 sites (82 additional sites above target outputs).
Silverleaf nightshade	Met expectations	A global silverleaf nightshade DNA survey and analysis to confirm the origin of silverleaf nightshade. The creation of a native Australian Solanum species location database. A comprehensive DNA study of Australian Solanum species. Guidelines and protocols developed for improved industry host-specificity testing. Improved germination procedures identified.
Biocontrol Hub and app	Met expectations	Seven additional weeds and 34 biocontrol agent descriptions uploaded.
Overall	Exceeded expectations	BCR report + case studies + survey: 90% of survey respondents indicated this project has influenced the policies and procedures for future weed RD&E in some capacity 95% of survey respondents indicated their involvement with the project had increased their skills and knowledge 100% of survey respondents indicated the project had increased their awareness and understanding of biological weed control options 99% of survey respondents indicated the project had increased their networks and interactions with peers.

Table 2: Sub-project output evidence against contracted outputs

Sub-project	Output description	Output status	Output evidence
Project initiation, management and coordination	Output 1(a) establish steering committee and hold regular steering committee meetings.	Met expectations	A combination of face-to-face meetings and teleconferences was utilised.
	Output 1(b) execution of agreements and contracts with partner organisations and service delivery agents as needed (to be determined by the grantee).	Met expectations	Contracts were executed with all partner organisations and service delivery agents. The contracts are available from MLA.
	Output 1(c) develop a project plan, extension plan and a monitoring and evaluation plan.	Met expectations	Provided as part of M1.
	Output 1(d) deliver an end-of-project evaluation and report. The evaluation report must report on the outcomes achieved against the program objective, including quantitative information on the outcomes achieved and independent expert analysis or expected an/or demonstrated quantifiable returns on investment.	Met expectations	See Appendix 7.4 Evaluation See Appendix 7.6 Individual sub-project draft final reports
	Output 1(e) deliver communication and extension of overarching project activities, which will include best-practice guides, progress reports and media releases. Project information (e.g. location of releases) will be uploaded to the Atlas of Living Australia website, and promoted via partners' general communication activities and websites.	Met expectations	See Appendix 7.2
Partnership model	Output 2(a) hold consultation meetings with stakeholders, including Local Land Services and local government groups.	Met expectations	Consultation meetings were held with representatives from Regional Weed Committees in NSW including Local Land Services weed coordinators, general managers and team leaders, and weeds officers from local councils from July 2016 to April 2018.
	Output 2(b) develop and implement a shared investment funding model.	Met expectations	A shared investment model was piloted in NSW as a result of shifting the focus of the previous Lantana and North Coast Weed Biocontrol Taskforce to a statewide group.

Sub-project	Output description	Output status	Output evidence
	Output 2(c) obtain commitment of the stakeholders to the business model with a clear understanding of the level of participation required for it to succeed.	Met expectations	Categories of commitment were determined as part of the model and organisations stated interest in participation. The prospectus describes participation contributions and benefits. The prospectus was supported by the NSW Weed Biological Control Taskforce in April 2018. The commitment has been from NSW jurisdictions.
	Output 2(d) set up a trial stakeholder investment partnership model run by stakeholders and state research agencies in New South Wales and Queensland.	Partially met expectations	A shared investment model was piloted in NSW. Queensland did not commit to partner in this model, however interactions between the jurisdictions do now occur (e.g. prioritisation, collaborations). Due to Queensland being already committed to an existing levy-based funding model, the project team was advised through interagency discussion that there was no impetus for current change in Queensland at this time. However, the project team also reported the Queensland funding model is under review (2017–current) to discuss regional contributions and local government's role in guiding priorities – analogous to the NSW model.
	Output 2(e) in conjunction with stakeholders, establish how data relating to agent release, redistribution and impact evaluation should be set up.	Met expectations	Data pertaining to agent release, redistribution and impact evaluation was collated and analysed on a weed-specific basis with the lead researcher responsible for the data.
	Output 2(f) hold meetings with partner organisations to assess efficacy of the model and potential for further national expansion.	Partially met expectations	Meetings were held with regional groups and jurisdictions. A hierarchical structure exists in NSW where regional needs are represented via regional weed committees and higher-level Local Land Services. Feedback was reported in meeting minutes, although this was not compelling evidence of awareness or support. Interstate partners (researchers/collaborators) were aware of the model. The opinion of the project manager was that the model was not sufficiently assessed by executive of interstate jurisdictions with them providing feedback on the opportunity for expansion in differing states.

Sub-project	Output description	Output status	Output evidence
	Output 2(g) under the model collectively prioritise, fund and initiate biocontrol projects in NSW and QLD.	Partially met expectations	Projects were initiated through the NSW Weed Biological Control Taskforce. The developing forum of participating organisations that now underpins a new model, was credited with assisting weed prioritisation and shaping projects in the Round 2 weed biocontrol project. It is not evident that other weed projects have commenced as a result of a new implementation model. Nevertheless, the core ingredients of the new model are in place in NSW to prioritise, fund and initiate projects in NSW – partners, forum for interaction. It is not evident that sufficient investment could be realised for a sustainable funding model, but five additional funders are likely to contribute to the pool next financial year.
	Output 2(h) link the business model outputs to the national weed biocontrol Atlas of Living Australia data hub, and seek to grow the business model across Australia by assessing likely participation of stakeholders outside NSW and Queensland in the new business model.	Met expectations	Project materials have been provided by research teams to support the Atlas of Living Australia. Concurrently the NSW Weed Biological Control Taskforce is developing a website that will include biological control research and implementation activities, to promote weed biocontrol, indicate availability of agents, provide access to training and networking opportunities, and contact list. Data pertaining to agent release, redistribution and impact evaluation will be collated. The incorporation of that data onto the biocontrol app has progressed and will be accessible via the Biocontrol Hub within the Atlas of Living Australia.

Sub-project	Output description	Output status	Output evidence
Blackberry	Output 3(a) develop a prototype mass-production system and assess viability of fungal material.	Met expectations	After testing different grains and a vermiculite-based substrate to mass produce inoculum of the Phytophthora species, the project selected the latter as the most suitable for subsequent glasshouse experiments. Mass production in large breathable polypropylene bags with filters was successful either using the vermiculite-based substrate or shredded sugarcane mulch. (Appendix 7.6). The project demonstrated that Phytophthora can survive in fresh, colonised vermiculite-based substrate stored at 4°C and ~22°C, but not at –20°C, for five weeks, five and 12 months. Bacterial and fungal contaminants were present in the inoculum after 12 months of storage and therefore viability assessments after 18 and 24 months were not performed.
	Output 3(b) experimentally test different application techniques for the fungus on blackberry plants.	Met expectations	An efficient protocol to produce standardised young blackberry plants from seed was developed and used throughout the project. Following an analysis of the relevant literature and consultation with colleagues at Murdoch University, a soil application technique was selected as the most appropriate for this system. The project tested different dosages of inoculum and demonstrated the importance of subjecting inoculated blackberry plants to regular simulated flooding conditions to reproduce the decline syndrome.
	Output 3(c) conduct at least two suitable field farm-based trial sites in partnership with stakeholders in each of ACT/NSW, Victoria and WA. Revised Output 3(c) conduct a scoping study on the prospect of the sawfly *Hartiga albomaculata* for blackberry biocontrol.	Met expectations	Farm-based field trials were cancelled after it was discovered some of the non-target plant species (e.g. Acacia) tested were adversely affected by the selected Phytophthora species. After consultation with MLA, the project team initiated field surveys in Europe, the native range of blackberry, to gain a better understanding of the host range of the stem-boring sawfly *P.faunus* (formerly known as *H. albomaculata*), previously identified as a possible candidate for blackberry biocontrol. Preliminary survey results were encouraging.

Sub-project	Output description	Output status	Output evidence
	Output 3(d) perform host-specificity testing of the fungus on different blackberries and non-target plant species.	Met expectations	The selected Phytophthora species was tested on seven blackberry varieties (different species and/or clones) propagated by seed or cane tip-rooting using the robust experimental methodology developed as part of the project. Plants from three of the seven varieties were significantly affected. The Phytophthora species was also tested on 45 non-target plant species (12 of these species are being tested for the first time as part of ongoing trials). 15 native species in the genera Acacia, Callistemon and Eucalyptus were significantly affected by the Phytophthora species. All pasture species tested, except *Trifolium repens* in one trial, were not significantly affected.
	Output 3(e) if results (Outputs 3(a) to 3(d)) indicate that the fungus may be a successful control agent for blackberry, prepare a plan for large-scale delivery of the agent to landholders. If the fungus is not a candidate agent, then make recommendations for next steps in the biological control of blackberry.	Met expectations	Results from glasshouse experiments showed the selected Phytophthora species could pose a risk to non-target plants species associated with blackberry in the field if it was to be redistributed on a large scale. A series of possible options for the next steps in the biocontrol of blackberry in Australia have been outlined in report. There is, however, no guarantee that investments in these options would generate effective and safe management solutions for blackberry applicable at the landscape scale.
	Output 3(f) Deliver a report analysing all results including two years of field assessments. Revised Output 3(f) Deliver a report analysing all results for biocontrol of blackberry, including outcomes from investigating potential biocontrol agents.	Met expectations	Analysis of all results and recommendations provided in final report (Appendix 7.6.2).
Cylindropuntia	Output 4(a) field collect new *Dactylopius tomentosus* biotypes and conduct host-specificity tests.	Met expectations	Field collections of *D. tomentosus* were successfully made from South Africa (2011 – one biotype), the USA (2012 – four biotypes) and the USA/Mexico (2015 – 16 biotypes). In total, 21 accessions were imported into an Australian quarantine laboratory for further host range and impact testing.
	Output 4(b) conduct molecular studies on all Cylindropuntia species found in Australia.	Met expectations	Molecular studies completed on all Australian material.

Sub-project	Output description	Output status	Output evidence
	Output 4(c) submit applications to field release suitable biotypes of *Dactylopius tomentosus*.	Met expectations	Preparation of four draft release applications, which were approved November 2017.
	Output 4 (d) release approved biotypes in the field at a minimum of 20 sites in NSW and QLD and monitor establishment.	Exceeded expectations	Between November 2016 and April 2018, 849 infected cholla biotype leaves were released at 36 sites in Qld, NSW, WA and SA. Confirmed establishment was recorded at 16 of these, with the remaining 20 release sites having not been checked due to their remoteness. Infected leaves were also supplied to 11 councils (NSW and QLD), two NSW Local Land Services (LLS) and two QLD Natural Resource Management (NRM) groups (Desert Channels and Southern Gulf) for further rearing and release.
	Output 4(e) establish rearing colonies for one South African and two USA biotypes subject to their approval to be field released.	Exceeded expectations	Laboratory rearing colonies (pure strains) of the cholla biotype (from South Africa) were maintained in Orange (NSW) and Brisbane (QLD) on loose leaves of *C. fulgida* var. *mamillata*. In addition, rearing colonies were established at Mt Isa, Longreach, Charleville (QLD), SA and WA. Laboratory rearing colonies of the *californica* var. *parkeri* biotype were established and maintained in Orange on loose leaves and in Brisbane on loose leaves of *C. prolifera*. Field rearing colonies of the *californica* var. *parkeri* biotype were set up at Cumborah (NSW) on *C. pallida*. Laboratory rearing colonies of the *Cylindropuntia* spp. biotype were established and maintained in Brisbane on loose leaves of *C. imbricata*, while the acanthocarpa X echinocarpa biotype was established and maintained in Brisbane and Orange on loose leaves of *C. tunicata.* Laboratory rearing colonies of the *bigelovii* biotype were established in Brisbane on loose leaves of *C. spinosior*.
	Output 4(f) develop a molecular diagnostic test to identify *Cylindropuntia* spp. samples.	Met expectations	Biotype matching to Cylindropuntia species was enhanced through the use of a molecular tool and more thorough growth habit observations of the individual cactus species.

Sub-project	Output description	Output status	Output evidence
	Output 4(g) report on the establishment of biotypes and, where the biotype has established, undertake redistribution.	Exceeded expectations	Long-term field monitoring sites were established for the cholla biotype on *C. fulgida* var. *mamillata* at Longreach in Queensland. Long-term field monitoring sites were also established for the *californica* var. *parkeri* biotype on *C. pallida* at Cumborah and Grawin, both in NSW. Monitoring commenced during November 2017 and will continue for the next two years. A long-term monitoring site was established at one of the two sites where the *bigelovii* biotype was released on *C. spinosior*. The site is situated at Bexley Station (Queensland).
	Output 4(h) prepare scientific papers based on results from completed host-specificity testing of South African and USA biotypes and molecular diagnostic tests.	Met expectations	Four peer-reviewed papers: 1) Host-specificity testing of the South African biotype 2) Host specificity of the first four USA biotypes 3) Molecular diagnostic tests 4) Host specificity of the USA biotypes collected in 2015. Three conference papers: Australasian Weeds Conference (x2) Queensland Weeds Symposium
	Output 4(i) provide the best evidence-based on-farm best practice recommendations to integrate biocontrol into production systems based on information available. Contributions from observations, reflections, and intuition should be included but noted as such.	Met expectations	Observations during monitoring efforts showed the greatest benefit of introducing the cholla biotype to this infestation was that once the agent was established, the infection of even the smallest cladodes by the cochineal was extremely high. Low inoculation loads are required to kill these emerging plants, therefore the cactus infestation would no longer require a high recruitment rate to sustain an increasing population.
Gorse	Output 5(a) develop monitoring protocols for GSSM.	Met expectations	Monitoring protocols were developed at the commencement of the project and sites were subsequently assessed for the presence of larvae by conducting a 10-minute (minimum) search of the point-of-release. The protocol balanced relative ease of detection of different life stages with typical time, resource and training constraints.

Sub-project	Output description	Output status	Output evidence
	Output 5(b) release and monitor GSSM at a minimum of 20 sites in Victoria, SA and Tasmania and record on the Atlas of Living Australia biocontrol portal for all monitored sites where GSSM has been established.	Exceeded expectations	More than 25,000 gorse soft shoot moths were collected from Tasmania for release at other sites. Monitoring for agent establishment, spread and abundance was conducted at eight existing release sites across Victoria, and 75 existing release sites across Tasmania (67 more sites than the project target of eight sites). Sites with the highest population densities suitable for collection were located in the Tasmanian midlands at Jericho and Melton Mowbray.
	Output 5(c) conduct field days at two sites in Victoria and two sites in Tasmania.	Exceeded expectations	More than 200 producers, land managers, scientists and students participated in more than 19 field days, workshops and related events in Tasmania and Victoria. In most cases, field days coincided with the collection, release or monitoring of agents, as they provided hands-on training and practical outcomes to participants.
Parkinsonia	Output 6(a) identify at least 18 field-release sites across Queensland, NT and WA and establish mass-rearing hubs for insect biological control agent pupae.	Exceeded expectations	At least 18 sites were identified for *Eueupithecia cisplatensis* (UU1) and *Eueupithecia vollonoides* (UU2). Mass-rearing hubs have been established for UU1 at Charters Towers, and for UU2 in Brisbane.
	Output 6(b) investigate physiological requirements for life history transitions for both insect biological control agents and publish results in an international journal.	Met expectations	A detailed understanding of the physiological differences in UU1 and UU2 has revealed that UU1 may be more cold tolerant, but UU2 may be more vigorous once its minimal developmental threshold temperature has been reached. The data have been analysed and graphs included in the final report.
	Output 6(c) release 10,000 pupae of each insect biological control agent across 18 sites in northern Australia and monitor establishment.	Exceeded expectations	Releases in excess of the initially anticipated releases have been achieved across northern Australia. More than 200,000 UU1 (76 sites; 116 releases) and 75,000 UU2 (24 sites; 37 releases) have been released on parkinsonia infestations across northern Australia.
Parthenium	Output 7(a) select release sites and establish one parthenium biological control agent in the glasshouse.	Exceeded expectations	30 sites were identified as potential release sites, with 15 sites deemed viable. The summer rust was established in the glasshouse during May 2016. Carmenta moth was established during January 2018.

Sub-project	Output description	Output status	Output evidence
	Output 7(b) undertake field visits to collect parthenium biological control agents in central Queensland and release them (those available in the field) at a minimum of eight sites in southern Queensland.	Exceeded expectations	30 sites were identified as potential release sites with 15 sites deemed viable. The seed-feeding Smicronyx weevil, the stem-boring Listronotus weevil, the root-feeding Carmenta moth, the stem-galling Epiblema moth and the summer rust were field collected from 16 sites in central Queensland. About 3209 adult Smicronyx weevils were released at seven sites. About 400 Carmenta moth and Listronotus weevil-infested parthenium plants were released at three sites. 100 Zygogramma beetles were released at one site. 800 winter rust-infected leaves were released at eight sites.
	Output 7(c) establish mass-rearing lab colony and field release of one biological control agent in southern Queensland.	Met expectations	Summer rust has been mass reared and released at 23 sites. Carmenta moth has been mass reared and released at four sites. Listronotus weevils have been mass reared and released at one site.
	Output 7(d) monitor agent establishment status at release sites in southern Queensland.	Exceeded expectations	Surveys were conducted *ad hoc* during release efforts. Plants were inspected visually for signs of pathogen or insect presence. In summary, the winter rust was recovered from 12 sites, the summer rust was recovered from 10 sites, the Smicronyx weevil was recovered from 14 sites, the Carmenta moth was recovered from four sites and the Listronotus weevil was recovered from five sites.
Silverleaf nightshade	Output 8(a) obtain approvals for importation of beetle.	Met expectations	Two Australian Government permits, required to import live *Leptinotarsa texana* beetles into quarantine in Australia, were obtained from the Department of Agriculture and the Department of the Environment during early 2016.
	Output 8(b) develop SLN plant cultures, source SLN shoot material and confirm sequencing protocols.	Met expectations	Plant cultures established during early 2016. Material sourced from SA and Victoria. DNA sequencing protocols were successfully developed and tested at the Wagga Wagga Agricultural Institute (NSW DPI).

Sub-project	Output description	Output status	Output evidence
	Output (8c) undertake host-specificity testing on plant species collected.	Met expectations	Host-specificity experiments tested 27 native non-target species, 19 cultivars of various crop and ornamental species and three other exotic species. *Leptinotarsa texana* utilised non-target species in no-choice and choice experiments.
	Output 8(d) import a colony of *Leptinotarsa texana* into quarantine and refine rearing methodologies to maximise colony development.	Met expectations	152 live *L. texana* adults were imported from South Africa on 14 April 2016 and the colony has been maintained. Rearing methodologies refined.
	Output 8(e) develop a detailed plan for specificity testing and propagule collection, using the centrifugal phylogenetic method to prioritise native and commercially important Solanaceae occurring in locations where the ranges of silverleaf nightshade and potential non-target species overlap. At least 30 species/cultivars will be collected, from at least 30 locations for host-specificity testing.	Met expectations	Comprehensively analysed phylogenetic (family) relationships between Australian Solanum species based on molecular techniques (DNA sequences) and advanced computer algorithms. Seed and cutting samples were collected from three designated field trips in addition to opportunistic field collections across NSW, Queensland, SA, WA and NT. During late 2017 *L. texana* was observed to attack the potato cultivar Nadine in a quarantine laboratory in Melbourne. Subsequent experiments resulted in damage to a group of related potato varieties. These observations disqualified *L. texana* from release in Australia.
	Output 8(f) complete DNA sequencing of SLN material from Australia and overseas.	Met expectations	A total of 341 specimens, representative of 162 Solanaceae species, were included in DNA analyses.
	Output 8(g) prepare a plan for next steps in the biological control of SLN. This should include detailed planning for release of Leptinotarsa in Australia if Outputs 8(a) to 8(i) indicate the beetle may be a successful control agent for SLN.	Met expectations	As a result of Output 8(e) it was determined that a release *L. texana* in Australia was not an option.
	Output 8(h) initiate Australian Government Import Risk Assessment procedures to obtain approval for release of SLN agent.	Met expectations	This has been completed, but not submitted due to the termination of *L. texana* as a viable agent.
	Output 8(i) prepare scientific papers on the project research.	Met expectations	Six papers have been drafted and are in varying stages of approval.

Sub-project	Output description	Output status	Output evidence
Biocontrol app	Output 9(a) develop and test the Android and iOS biocontrol app and link for download from the Atlas of Living Australia biocontrol portal.	Met expectations	Biocontrol Hub is accessible via https://biocollect.ala.org.au/biocontrolhub The app can be downloaded from both Google Play and the App Store.
	Output 9(b) upload content for Australian weeds and biocontrol agents onto the Atlas of Living Australia biocontrol portal.	Exceeded expectations	28 target weeds, information and descriptions for 84 biocontrol agents released for these weeds. New content written for each target and agent.
	Output 9(c) conduct app beta testing with project partners (NSW, Tasmania, Victoria and Queensland), private consultants (Tasmania and Victoria), NRM/Landcare Collaborators (SA and Victoria) and selected producers (Tasmania and Victoria). Demonstrate app to 200 producers/stakeholders at agent releases in Queensland, NSW, Victoria, Tasmania and SA, including at least eight field days in Victoria and Tasmania. Publicise app through project partner websites and social media, project stakeholder forum and project-related media releases. Google Analytics will be used to measure and report on uptake.	Met expectations	Testing occurred with 220 producers and was demonstrated through 11 field days. Promotion was undertaken by other sub-project partners, a project stakeholder forum (29/11/17) and via conferences and media activities. A Google Analytics report is included in sub-project report.

3.2 Contribution to program objectives

The objective of the Rural R&D for Profit program is to realise significant productivity and profitability improvements for primary producers, through:

- generating knowledge, technologies, products or processes that benefit primary producers
- strengthening pathways to extend the results of rural R&D, including understanding the barriers to adoption
- establishing and fostering industry and research collaborations that form the basis for ongoing innovation and growth of Australian agriculture.

In some weeds, impact at scale from biological control agents can take considerable time (30 years) while for other weeds the time to impact is much shorter. The *Fast-tracking* project has demonstrated that human intervention in weed biocontrol systems, supported by a dynamic and collective knowledge base and innovative technologies, can, through a collaborative and consultative approach, hasten the impact and scale of biocontrol efforts, boosting primary producers' productivity and reducing their costs.

The ability to identify, rear and release a multitude of agents, each acting on different parts of the plant and across seasons, will also increase impact. To that end, research to facilitate an efficient and time-effective discovery-to-delivery pipeline, supported by consultative and collaborative processes, has the greatest opportunity for cumulative success.

The *Fast-tracking* project contributed significantly and successfully across all three Rural R&D for Profit program objectives. These objectives underpin the required human intervention critical to long-term success in weed management.

The *Fast-tracking* project generated knowledge, technologies, products and processes that benefit primary producers through further exploration and understanding, refining and improving processes and protocols, and identifying the relevant human resources with whom to form partnerships and collaborations.

- Exploration and understanding – By exploring and better understanding weed and agent biology and ecology (through the use of traditional and innovative technologies, such as the molecular diagnostic tool used in the Cylindropuntia sub-project) the project has been able to expedite the discovery-to-delivery pipeline.
- Processes and protocols – Improved rigour in the science and a greater level of stakeholder engagement in the RD&E processes has demonstrated benefits through enhanced stakeholder and community confidence in weed biocontrol as a tool (e.g. silverleaf nightshade sub-project).
- People and partnerships – Gaining a greater appreciation for the breadth of potential stakeholders in the weed RD&E pipeline, their core business, capacity and ability to engage, has hastened the impact and scale of biocontrol efforts across the project (e.g. parkinsonia and parthenium sub-projects).

The *Fast-tracking* project strengthened pathways to extend the results of rural R&D, including understanding the barriers to adoption by managing expectations, delivering education and training, and developing an interactive repository for historical, current and future biocontrol RD&E knowledge and information.

- Managing expectations – Engaging with stakeholders along the research, development, extension and adoption (RDE&A) pipeline at the outset of the project established realistic expectations, avoiding frustration and disengagement when project goalposts shifted (e.g. blackberry sub-project).
- Education and training – A combination of conference presentations, workshops, field days and intensive training opportunities developed skill and capacity of extension agents and land managers, facilitating a smoother transition from discover to delivery across the nine biocontrol agents released at more than 270 sites through the project.
- Interactive repository – By capturing historical and current knowledge and information in a single accessible repository through the Australian Biocontrol Hub and smartphone application, the project has established a living legacy, which facilitates ongoing connections between stakeholders along the RDE&A pipeline.

The *Fast-tracking* project established and fostered industry and research collaborations that will form the basis for ongoing innovation and growth of Australian agriculture.

- Industry and research collaborations – More than 200 landholders and land managers, five federal government agencies, 26 state government agencies, 17 local government areas, 12 community groups, 12 regional NRM groups, seven industry organisations, six universities and 15 international bodies participated in this project.

The industry and research collaborations established and fostered across collective sub-projects that formed the *Fast-tracking* project addressed the historical fragmentation that characterises the biological weed control RDE&A operating environment and demonstrated clear efficiencies of resource use (human, cash, infrastructure). In addition to efficiencies gained by capitalising on existing resources, delivered through the core businesses of collaborators at no additional expense to this project, the two-way flow of information that occurred through stakeholder collaboration enhanced the connectivity and delivery across the various segments within the pipeline.

> 62% of organisations surveyed said they had significantly expanded their networks and contacts as a result of being involved in the project.

The value of the industry and research collaborations established through the *Fast-tracking* project will – if nurtured – reap benefits for ongoing innovation and growth of Australian agriculture for years to come.

For primary producers, the collective impact of the cumulative achievements across the *Fast-tracking* project is greater engagement with, and improved access to, best practice weed management information and technology, a superior range of biocontrol agents, and enhanced confidence in the biocontrol RD&E pipeline, which will deliver faster impacts at landscape scale. With this collective impact will come associated increases in profitability through higher productivity and lower costs.

The RD&E pipeline is critical for success – from the laboratory onto the target weed. Delivery networks and partnerships created and developed in this project allow more agents to be delivered to where the weeds are situated. This process of human intervention greatly assists the natural spread of the agents, reducing time to impact and so producer benefit.

Awareness-raising activities across the delivery pipeline increase land managers' knowledge of weed biocontrol and so application and use of biocontrol agents and approaches. Use of agents on non-grazing lands by local government and others will reduce the weed population and potential movement onto livestock-producing landscapes.

Figure 9. Before (left) and after (right) photos taken at the Leander release sites of the Cylindropuntia project. Photo courtesy NSW DPI.

Training and passing on skills from researchers to land managers and other stakeholders replicates the researcher knowledge and effort, and allows local experts to focus on local issues. The Australian Biocontrol Hub and the associated smartphone application can provide access to the collective information across the RD&E pipeline, improving efficiency of information sharing and delivery of the benefits.

> "We did a single release on a 1ha test plot and, within 16 months, 100% of those plants were infected with cochineal and 95% of the plants had died."
>
> Andrew McConnachie – project leader Cylindropuntia sub-project

> "In March 2016 the research team released a cochineal bug that only worked on this particular cactus. The release or nursery plot – which we nicknamed the media plot because we were always taking people to look at it – was about 100m^2 but I was amazed at how well it spread. The researchers came up six months ago and on one plot of more than 3000 cactus plants, only four were still alive. It's just terrific."
>
> Elizabeth Clark – producer involved with the Cylindropuntia sub-project
> Leander Station, Longreach, Queensland

4 Collaboration

Establishing and fostering productive collaborations has been critical to enabling the *Fast-tracking* project to meet, and in many cases exceed, the required outputs.

The range of partners – from individual landholders to government and international research organisations – resulted in increased efficiencies and higher-than-expected achievements within the project.

“So far it’s looking really beneficial and it’s been great to work collaboratively with researchers and other organisations on this project (Cylindropuntia).”

Andrea Fletcher – Senior Weeds Officer, Walgett Shire Council, NSW

Critical to these achievements were collaborations – both domestic and international – that supported and facilitated the discovery-to-delivery RD&E pipeline, particularly across the following phases:

- discovery (e.g. agent or process)
- testing (e.g. suitability and host specificity)
- delivery (e.g. release and redistribution).

The ability to utilise both the intellectual and technological capacity and skillsets across an extensive range of partnerships (some through formal contractual obligations, but many through invaluable in-kind support) was a core element behind the success of the weed biological control achievements of this project.

Table 3 offers a subjective representation of the comparative jurisdictional effort invested across the three key phases of the discovery-to-delivery RD&E pipeline mentioned above.

Table 3. Relative partner contributions to key phases of the discovery-to-delivery RD&E pipeline by jurisdiction for the *Fast-tracking* project.

Sub-project	Pipeline phase	International research organisation	Australian research organisation	Local government	Community group	Producer or land manager
Blackberry Cylindropuntia Silverleaf nightshade Parkinsonia	Discovery	xx	xxx			
Blackberry Cylindropuntia Silverleaf nightshade Parkinsonia Parthenium	Testing	xxx	xxx			
Parkinsonia Parthenium	Delivery – rearing and release		xxx	xx	xxx	xxx
Gorse Parthenium	Delivery – redistribution		x	xx	xx	xxx
Efficiency and knowledge exchange		x	x	x	x	x

x = moderate xx = considerable xxx = substantial

Figure 10 and Figure 11 offer a visual insight into the geographic spread and diversity of Australian and international stakeholders who contributed to the *Fast-tracking* project in some way – through financial, technological, intellectual, physical or in-kind support.

> "In excess of 340 volunteer hours have been contributed to this project as a result of the collaboration with community partners and individual landholders."

Gorse project final report (see Appendix 7.6.4)

Figure 10. Location and type of collaborator associated with the *Fast-tracking* project within Australia.

International partners (Figure 11) were crucial in at least five of the *Fast-tracking* sub-projects to facilitate the initial work on weed species and identify control agents in their native range.

Staff from the project teams worked alongside these organisations to ensure an in-depth understanding of the agent, and to facilitate the importation under permit into Australia.

Existing international collaborations were strengthened during the *Fast-tracking* project, which will help build and sustain long-term collaborations to facilitate future weed biological control efforts at a local level.

Figure 11. Location and type of collaborator associated with the *Fast-tracking* project outside Australia.

A list of the *Fast-tracking* project primary partners, partners and collaborators is presented in Table 4.

Table 4. *Fast-tracking* project primary partners, partners and collaborators

Sub-project	Primary partner	Partners	Collaborators	
Partnership model	NSW DPI		NSW Weed Biological Control Taskforce The Weeds Society of NSW Mid Coast Council Tamworth Regional Council Upper Hunter Weeds Authority Eurobodalla Shire Council Central Tablelands Local Lands Services Rouse County Council NSW National Parks and Wildlife Service Hunter Local Land Services Hawkesbury River County Council NSW Crown Lands	

Sub-project	Primary partner	Partners	Collaborators	
			Northern Tablelands Local Lands Services North Coast Local Lands Services Queensland Department of Agriculture & Fisheries Landcare Biodiversity and Conservation Team – Lincoln and Auckland, NZ AgResearch, Lincoln NZ Greater Wellington Regional Council, Wellington NZ Horizons Regional Council, Wanganui NZ Hawkes Bay Regional Council, Napier NZ Auckland Council, Auckland NZ Department of Conservation, Auckland NZ	
Blackberry	CSIRO	Murray Local Land Services Agriculture Victoria Murdoch University	Mitta to Murray Blackberry Action Group CSIRO European Laboratory	
Cylindropuntia	NSW DPI	QDAF	Castlereagh Macquarie County Council Bourke Shire Council Bulloo Shire Council Paroo Council Longreach Regional Council Barcaldine Regional Council Murwell Shire Council Balonne Shire Council Quilpie Shire Council Central Highlands Regional Council Blackall Tambo Regional Council Southwest Natural Resource Management Group Southern Gulf Natural Resource Management Group	

Sub-project	Primary partner	Partners	Collaborators	
			Desert Channels Natural Resource Management Group Bush Heritage, South Australia Natural Resources SA Arid Lands, South Australia Queensland Murray-Darling Committee Condamine Alliance North West Local Land Services Department of Agriculture and Food WA Department of Environment, Water and Natural Resources SA Department of Primary Industries and Regions SA	
Gorse	Agriculture Victoria	South West Goulburn Landcare Natural Resources Adelaide and Mount Lofty Ranges Victorian Gorse Task Force Connecting Country, Vic NSW DPI Tas Biocontrol	Natural Resources SA Murray-Darling Basin Industry & Investment NSW Southern Midlands Council Ballarat City Council Baynton Sidonia Landcare group University of Melbourne Deakin University Department Environment, Land, Water and Planning VIC	
Parthenium	CSIRO		Queensland Murray-Darling Committee Maranoa Landcare Junction View Pest Management Group Oxley Catchment Group Healthy Land and Water North Burnett Regional Council Bundaberg Regional Council Biosecurity QLD Landholders	

Sub-project	Primary partner	Partners	Collaborators	
Parkinsonia	Department of Agriculture and Fisheries, Queensland	Pilbara Mesquite Management Group	Department of Agriculture and Food WA Rangelands NRM WA Northern Territory Department of Land Resources Management	
Silverleaf nightshade	Department of Primary Industries and Regions South Australia	South Australian Grains Industry Trust	University of Melbourne Deakin University Outback Pride Fresh Bowen Gumlu Growers Association Graham Centre for Agricultural Innovation AusVeg United States Department of Agriculture Herbarium of SA South Australian Seed Conservation Centre AgriBio (La Trobe University campus, Melbourne) Invasive Species Unit of Biosecurity SA University of Texas US Army Corps of Engineers Department of Environment and Water, SA NSW Department of Primary Industries	
Biocontrol Hub and app		CSIRO's Atlas of Living Australia	University of Melbourne (Faculty of Science)	

Examples of collaboration within the sub-projects

Partnership model

As part of the initial background work, international examples of shared investment funding models were reviewed. As a result, a research trip was made to New Zealand and consultation meetings were held with eight local organisations to gain insight into the successes and lessons learned from an existing partnership model led by Landcare Research New Zealand.

Meetings with nine personnel from Landcare and council representatives of the Biocontrol Collective New Zealand were held to facilitate the development of a collaborative funding model to aid sustainable biological control funding in NSW.

Meetings were held with key personnel of New Zealand's Biocontrol Collective including employees from Landcare, AgResearch, Department of Conservation and representatives from five regional councils.

Blackberry

The component of the project focusing on blackberry decline was based on a collaboration between CSIRO and Murdoch University. This collaboration was established years before this project, during initial investigations of the blackberry decline syndrome in WA, which involved a PhD student and researchers from Murdoch University, and a Perth-based researcher and technical officer from CSIRO. The CSIRO–Murdoch University collaboration was continued for this specific project.

Murdoch University played an important role in the project by re-isolating Phytophthora species from blackberry samples collected by CSIRO staff at sites where the decline syndrome had been observed. These collaborations allowed efficient use of cross-organisational resources and skillsets to deliver on the project objectives. Without these new isolates the project would have been discontinued in 2016.

Cylindropuntia

Collaborations in the Cylindropuntia project have led to greater access to agents for releases of the biocontrol agents not only in Queensland and NSW, but also across SA and WA. Champions of the project were created in regional areas via partner organisations, which led to increased awareness and identification of infestations and additional release activities. Working with other organisations will facilitate the ongoing monitoring of release sites and enable greater engagement with other land mangers who are tackling the weed.

> “This project allowed very valuable networks to be built between departments and between researchers and extension staff. It outlined how research has on ground outcomes to producers. There has also been a noticeable increased awareness and enthusiasm for biological control options within the organisation. Overall, great outcomes on ground, and great outcomes socially.”

Survey participant, NSW State Government

Parkinsonia

Collaborations across states and with community groups and producers allowed activity to cover the entire distribution of parkinsonia across northern Australia. This was achieved through collaborations between researchers, extension officers, biosecurity officers and stakeholders across Queensland, NT and WA.

This collaboration across more than two dozen agencies and groups is being extended through work on other weeds (beyond the life of this project) through a related Rural R&D for Profit program project.

More than 100 on-farm visits occurred during the life of this project. On several of these visits engagement with multiple farm managers and landholders occurred and the role of weed biological control in integrated weed management programs was discussed.

More than 50 landholders, farm managers and regional weeds officers participated in field releases for this project.

Parthenium

Community and local government involvement has been paramount to the success of this sub-project. Several community organisations, such as Queensland Murray-Darling Committee, Maranoa Landcare, Junction View Pest Management Group, Oxley Catchment Group, Healthy Land and Water, North Burnett Regional Council, Bundaberg Regional Council and individual landholders actively participated in the rearing and release program. The project also helped to train more than 36 community group members in the rearing and field release of various parthenium biological control agents.

The North Burnett Regional Council demonstrated exemplary interest, participation, contribution and involvement in the project, which shows in the success the region had in establishing all five of the released agents at most of their sites. Their collaborative effort led to a pre-proposal for a joint project (between QDAF and North Burnett Regional Council) specifically addressing the evaluation of parthenium management strategies in the region.

Gorse

Collaboration between on-ground and interstate partners was strengthened throughout the project, and new partners were identified. Community groups were invaluable in providing leads on potential release sites, assisting with releases and monitoring of sites.

In excess of 340 volunteer hours were contributed to this project as a result of the collaboration with community partners and individual landholders. Collaborative efforts expanded during the project, with NSW DPI and an additional SA NRM group participating in gorse soft shoot moth redistribution.

Developing linkages with the University of Melbourne and Monash University facilitated access to modelling expertise, which would not otherwise have been available to the project. For example, a paper on the application of Bayesian networks to inform site selection is now planned. Such models could be used as part of an adaptive management approach to biological control agent introduction.

Silverleaf nightshade

Six science and technology students from the University of Melbourne and Deakin University completed supervised internships with the silverleaf nightshade project. The students contributed 80–100 hours each, and assisted with quarantine laboratory and glasshouse general duties, plant and insect culture maintenance, experiment assessments and data entry. They also received training in the use of specialised equipment and software, such as AutoMontage. The internships contributed a full subject credit towards the students' undergraduate and Masters degrees, provided valuable work experience in a modern science facility, and strengthened their knowledge and understanding of biosecurity and classical biological control. Each of the interns has gone on to full-time employment in the biosecurity and crop protection fields, or further study.

Biocontrol Hub and app

Capitalising on an existing framework, the ALA website enabled this project to build on lessons learnt and utilise a platform supported beyond this project. University of Melbourne Science faculty technology interns assisted with drafting content for the target weeds and agents. The other sub-project leaders also provided content for the hub.

5 Extension and adoption activities

A range of extension and adoption activities, including workshops, field days, information sessions, training activities, conference presentations and field collections, was undertaken during the project to engage with the stakeholders and potential beneficiaries of the project (e.g. producers and other land managers).

The priorities for activities were to: engage, inform, educate and upskill participants. Some events were 2–3 hours, while others were full-day activities and included training on specific skills to enable participation in agent collection, mass rearing, release, redistribution and ongoing monitoring activities.

The emphasis for three sub-projects (Cylindropuntia, parkinsonia and parthenium) was to hasten agent spread through mass rearing and distribution efforts. The gorse project extension and adoption efforts focused on collection and redistribution of a well-established agent. Hastening spread was evidenced where projects exceeded release targets (e.g. parkinsonia) and early monitoring indicated agent establishment (e.g. parthenium) and, in some cases, impact on the target weeds (e.g. Cylindropuntia).

> “It is refreshing to encounter enthusiastic and dedicated people who are willing to share their knowledge and patience with individuals who are just beginning to understand the complexities of pest weeds and their potential impact on our environment.”
>
> Survey participant, Queensland local government

Field days and workshops

Field days and workshops formed an important component of engagement and redistribution activities because they contributed to each of the sub-project objectives. More than 40 field days and industry workshops were held across the Cylindropuntia, gorse, parthenium and parkinsonia project activities. Participation figures were not reported for all events, but more than 290 people attended extension activities across the sub-projects. More than 230 people participated in training activities conducted by the sub-projects. These figures do not include the large number of site visits and one-on-one work undertaken with land managers to facilitate agent releases on their properties.

Most of the events aimed to:

- transfer knowledge of agent biology, site management and monitoring, and integrated weed management to next users (for example, state government weeds officers, public land managers and Landcare facilitators) and to end users (producers, Landcare group members and weeds contractors)
- involve next users and end users directly in biological control site assessment, monitoring, agent collection, release and redistribution
- ensure agent releases were integrated with local and regional weed management planning

- capture observations and local knowledge of production systems, past weed management efforts and approaches, and prevailing conditions that could impact biological control.

As a result of strong collaboration, many project partners participated in training opportunities to upskill their staff or volunteers. This has enabled others to assist with aspects of project activities and will support ongoing monitoring activities at many sites. For example, the parthenium project helped to train more than 36 community group members in the rearing and field release of the various parthenium biological control agents. This contribution to the *Fast-tracking* project utilises local resources and enables project researchers to expand their reach and impact, or to reduce the time and travel to visit sites that may be more difficult to access.

Free information sharing occurred between project partners and the extensive network of collaborators. Information exchange occurred via both print (e.g. reports and guidelines) and email, and via online media platforms (e.g. sub-project websites and the Biocontrol Hub and app). This multi-faceted activity increased awareness and opportunities for participation.

Broader knowledge and information exchange

In addition to the extension and adoption activities aimed predominantly at land managers and regional extension agents, the project team capitalised on opportunities to share Australian weed biocontrol project lessons, outcomes, knowledge and information with international counterparts through a range of presentations and papers. Project team members delivered at least 22 papers or presentations to state, national and international conferences.

Through the project multiple opportunities were taken to engage with undergraduate and postgraduate students to raise awareness of the opportunities for and discovery-to-delivery processes involved with biological control, as a key component of an integrated weed management strategy.

Recommendations on increasing awareness and adoption

Efforts carried out during the project to hasten the delivery and extend the impact of biocontrol across the six national priority target weeds have been commendable. To ensure the ongoing impact from these efforts, the following recommendations have been proposed:

- Mass rearing and release of agents at more sites is the only way to speed up their distribution. To facilitate this, access to agents is a critical factor and relies on a number of organisations to make this possible.
- Ongoing monitoring to record the impact of the agents on the target weeds is also required. The Australian Biocontrol Hub will be utilised to record this information, although adequate promotion of the site will be needed to broaden its awareness and uptake.
- Twice a year run a campaign on weed biocontrol which promotes citizen science, where to access agents and what agents may be at your place. The focus would be recurring events to increase awareness and information exchange. Have mass-reared agent supply available (first point above), then stimulate demand through a regular awareness campaign.
- A number of Landcare groups have already participated in the individual sub-projects, but a broader campaign to engage these groups and their members would increase the potential

on-ground collaborations. Many of these groups have weed management as a focus and are willing to be involved. Some may have the capacity to be agent nursery sites.

- Work with agribusiness resellers to educate and inform them of how weed biocontrol can be implemented as part of an integrated weed management approach. Local governments also have weeds officers and tapping into this network to continue to increase their skills and knowledge in biocontrol options will ensure they are aware of options available.
- Awareness activities within areas where weeds have the potential to spread are needed to educate landholders about the weeds, how they spread, early detection and available control methods. This will enable landholders to be proactive rather than reactive.

6 Lessons learnt

A number of lessons were learnt during the project, some of which are being incorporated into current biocontrol efforts, and will be used in shaping future weed biocontrol projects. Throughout the implementation of the project, where possible, changes were made on the run to activities and sub-projects to incorporate the learnings.

Individual sub-projects have also identified lessons learnt and these are documented in the sub-project final reports (Appendix 7.6).

Working with partners and collaborators

More than 120 organisations and more than 200 individual landholders were involved with this project. As a result the strongest lesson was that fast-tracking success requires working with, and sustaining relationships with, a broad range of collaborators and the people who make up these organisations.

Managing expectations – Often collaborators have unrealistic expectations of what weed biocontrol can deliver, underestimating the timeframe for agents to establish and impact the weed population. They have the view that biocontrol is going to be a silver bullet solution and a quick-fix option. When working with community groups, a clear understanding about the scope of the project, what's involved and contributions being made, need to be clearly articulated and understood by all parties. Taking the time to develop relationships with project partners and maintaining regular communication throughout the project can help manage expectations.

Educating landholders about how biocontrol works and how each specific agent spreads, including establishing clear expectations around timeframes for agent establishment and impact, are critical. On one occasion, project staff undertaking releases found weeds had been sprayed where the land manager had presumed the agents were not working, subsequently killing the weed and established agents. The expectation was plants would be dead following the release and establishment of agents. In many cases biological control agents weaken plants, making them more vulnerable to other stresses, causing direct death of the weed.

Encouraging and educating land managers on how to integrate conventional control with biological control is key to avoiding unintended outcomes and managing expectations.

Despite these challenges, most landholders are strong supporters of biocontrol and contribute their time and resources freely to assist with the control of their problem weed and ongoing monitoring.

Adaptability – Project teams need to accept and adapt to changing circumstances or situations throughout the life of a project. Open and transparent communication with project partners and stakeholders ensures relationships are well managed if and when circumstances change. When circumstances changed in the blackberry project and the prospective agents were found to be unsuitable, partners who had committed to supporting field trials of the agent were still avid supporters of the project, even though field trials did not eventuate, because relationships were managed well.

Without the involvement and contributions of all partners, undertaking project activities is much harder. At different times, issues may arise and impact on the ability to contribute as desired. This can include funding, personnel or project implementation. Results from the project activities may affect what happens next and the direction of the project.

Contingency resourcing to cover unexpected withdrawal of potentially valuable partners is desirable. For example, the NT Government was a key contributor to earlier parkinsonia biological control projects. Unfortunately, due to budget reductions, they could not formally commit to participating in this project. However, they had informally indicated their ability to contribute to the mass rearing and release outside of the formal relationships of this project. During the first year of the project further staffing cuts in the NT Government meant they could not assist in any way. Though CSIRO and QDAF stretched resources to cover off on making some releases in the NT, securing additional financial resources from this project may have been a way to sustain NT Government's capacity in the context of this project and weed biological control in general.

Diversity of partners – Working with a diverse range of partners enables greater empathy and sharing across organisations. This enables a better understanding by researchers of the pressures being faced by land managers in different contexts. The direct engagement of researchers with a cross-section of agencies also enabled these agencies to appreciate the processes involved in the scientific investigations of biological weed control solutions.

The involvement of the North Burnett Regional Council in the parthenium sub-project is an example of how strong participation, contribution and engagement with a local stakeholder can lead to long-term partnerships and so flow-on benefits for biocontrol impacts. As a result of the council's efforts, the region established all five of the released agents at most of their sites. Their collaborative efforts have led to a pre-proposal for a joint project (QDAF and North Burnett Regional Council) specifically addressing the evaluation of parthenium management strategies in their region.

Broader industry consultation – In cases where important plants are potentially at risk from potential biocontrol agents (e.g. the risk of SLNB impacting eggplant), it is important to engage with stakeholders during the early stages of the project. Early consultation helps develop relationships and provides an opportunity to liaise with stakeholders over the project scope and possible implications, giving them confidence that due process and diligence is being observed and their interests are being considered. Understanding how the research may impact on industry, and making the time to keep them informed of progress, is vital.

The silverleaf nightshade sub-project team liaised with vegetable growers – eggplant growers, in particular – and their advisors. The face-to-face approach was well received and stakeholders provided feedback to the project team that they rarely felt they were consulted properly in many other instances. The consultation worked well, with industry leaders aware of the situation and able to communicate with and reassure any growers with concerns.

Protocols, procedures and techniques – doing things the right way

Across all projects the procedures and protocols implemented were critical to ensure the activities were being carried out with sufficient rigour and due diligence to limit any potential risks that may occur.

Due diligence – Time and effort in making sure experimental procedures were rigorous before embarking on comprehensive testing was well spent.

Agent approval process – The process for getting biocontrol agents approved for release can take 12–24 months per application. This timeframe needs to be factored into projects from the outset to avoid having impacts further down the track. The cholla biotype took 13 months to be approved. The next four biotypes took about 16 months as the regulators needed to decide on whether each application had to be assessed separately. The decision to approve all biotypes (subject to testing and going through one generation in quarantine) was a huge benefit for the project.

Weed identification – A major challenge facing the Cylindropuntia sub-project was the number of *Cylindropuntia* spp. that were targeted. Essentially, the project covered eight weed species and 21 biotypes of the same biocontrol agent. The screening of these biotypes was time consuming, as individual trials sometimes ran for more than 12 months, putting pressure on overall project timelines. Screening tools (e.g. molecular identification) can improve precision and efficiency in testing activities as well as reducing timeframes for identification of suitable biotypes.

Value of molecular biology (DNA) techniques – Host-specificity test lists are a critical component of a safe biocontrol project. Constructed well, they minimise the risk of unexpected off-target damage to an acceptable level. The silverleaf nightshade project study has demonstrated the value of molecular biology techniques to compare DNA sequences between different plants. In most cases this evidence has confirmed existing models, but in a few cases the new evidence may change the list of plants chosen to investigate with host-specificity testing. In addition, DNA studies to determine the most likely origins of Australian SLN (i.e. central USA) has provided strong guidance for the most likely places to source co-evolved, effective agents.

Importance of field monitoring – It is critical to ensure monitoring processes and procedures are established before site releases commence to ensure best practice of release and establishment of the insect.

Monitoring is necessarily constrained by the difficulty in detecting agents when populations are low (especially in the first 1–3 years post-release, but sometimes longer). Producer and land manager expectations of agent detection need to be carefully managed. This was a challenge in aspects of the gorse project where detection of agents was sometimes difficult and landholders exhausted considerable time searching for agents. A method that shows promise is the application of detection experiments at the start of a new redistribution project. Data from detection experiments could be used to provide advice on the minimum number of surveys needed to be reasonably certain an agent is absent, given it was not detected. Land managers and producers would therefore be better informed when making decisions whether to persist with, or abandon, release sites.

Data sharing and acknowledgement – Development of the Australian Biocontrol Hub and app raised questions about sharing and using data that is publicly available under the ALA's Creative Commons licence, but may be sensitive or belong to a research agency, for example. In response, guidelines were written that instruct users in the appropriate use and acknowledgment of data accessed on the Australian Biocontrol Hub and app. The guidelines include instructions that can be used for certain data types typically encountered in biocontrol, for example protecting (embargoing) the location of a new release site for a specified time period before it is shared with the public. In projects where information from external sources is being shared, developing such guidelines from the outset would be valuable.

Project and program management

Program coordination – Project management is relatively simple. Delivery of program outputs and benefits adds a dimension that requires more than managing projects and reports. Communications, evaluation processes and cross-team interactions are critical to success and are projects within themselves. The series of Rural R&D for Profit program projects undertaken by MLA, and many other programs, reinforces the need for dedicating resources to program management.

When working across multiple sub-projects and with multiple partners, a coordinated approach and support for activities assists in ensuring the deliverables and achievements come together. Opportunities that arise from working with each of the sub-projects can be utilised and shared with the others. This could be the creation of project collateral (e.g. video development) or attendance at events, which are enhanced by knowing what other component projects are doing. Sharing the lessons learnt from each other during cross-team interactions helps improve the way things are done. It is critical that support for the project team and program management be implemented at the outset of the project to enable processes and practices to be effective and efficient.

7 Appendix – additional project information

7.1 Context of weed biocontrol in Australia

There are numerous compelling reasons why Australia needs to plan and coordinate its investment in weeds RD&E. As a huge, sparsely populated, recently disturbed (in evolutionary terms) biodiverse continent, Australia is prone to the invasion and spread of undesirable plants – weeds.

The impact of weeds on Australia's agricultural industries is well documented. Integral to the challenge is the quantity and diversity of significant weeds (e.g. woody weeds, grassy weeds, annual versus perennial weeds) across the landscape. Each type of weed requires a potentially different control process, given its contextual environment as well as the control options available.

The cost of weed control to agriculture is not only foregone production, or environmental damage coupled with control costs (both labour and inputs), but also the significant RDE&A costs including:

- understanding individual weed species' ecology and biology
- investigating multi-pronged management approaches, which may include mechanical, chemical and biological options
- extending research and development outcomes to ensure a successful path to adoption of new knowledge by land managers (i.e. presenting a motivating, informative and instructive value proposition to support and facilitate behaviour change).

Recognising the above, and the approaches and lessons from the past, the Rural R&D for Profit program *Fast-tracking and maximising the long-lasting benefits of weed biological control for farm productivity* project embarked on a process underpinned by coordination and collaboration to hasten and enable impact at scale.

The weed management puzzle

Three key components make up the RDE&A weed management puzzle to address numerous weeds in differing contexts – each component is critical to developing and delivering solutions:

- large-scale national initiatives (e.g. the National RD&E Priorities for Invasive Plants and Animals (IPAC) 2016–2020 and the Australian Weeds Strategy 2017–2027[1])
- state jurisdictions (research agencies, NRM bodies, land management agencies)
- local land managers (e.g. agricultural producers and public land managers).

Weed incursion and spread mirrors an exotic disease outbreak, albeit in slow motion, often failing to attract the strategic and sustained effort of a crisis event. Consequently, funds and effort are invested in a band-aid or fragmented approach, where causal factors are insufficiently addressed and momentum is lost.

With significant investment having already taken place during the past decades (as discussed below), the solution is not perhaps throwing more money at the same business model, rather collectively utilising and developing financial, human (expertise and skills) and infrastructure resources in a coordinated and sustained approach, building programs based on guiding principles that overcome fragmentation and ensure maximum resource use efficiency.

A historical perspective

The historical investment and operating environment of weeds RD&E is crowded and complex.

Rural RD&E operates within a complex system, which links funders, providers and end users. It comprises networks of funders, those who undertake R&D, the extension and consultation networks (E) that support the flow of information and transfer of technology between industry and researchers, and the policy and institutional frameworks that support these activities.

Within this complex environment, the RD&E response, particularly in respect to environmental benefits through landscape-scale approaches, has not been robust, but rather characterised by boom-and-bust funding directed into initiatives under a range of fragmented national, state, regional and local strategies and priorities (see Figure 12).

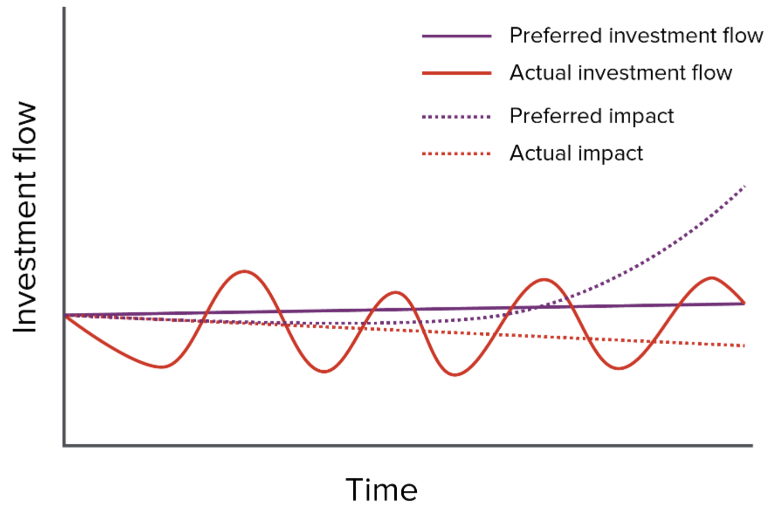

Figure 12. Conceptual model of weed investment flows and impact.
Source: Centre Invasive Species Solutions draft investment plan 2018

National significance

On 1 June 1999 the inaugural list of 20 Weeds of National Significance (WoNS) was announced. Since the announcement much work has been undertaken in managing the 20 species.

An independent review in 2007 concluded a nationally strategic approach had been highly successful, leveraging consistent multi-jurisdictional activity on high-priority species.

The Natural Resource Management Ministerial Council (Resolution 15.7, 21 May 2009) endorsed a three-phased approach to national management of the WoNS species, which aimed to make the most cost-effective use of limited national coordination resources available from public funds.

It is difficult to estimate the total amount of funding invested since the mid-1990s in federal weeds programs, as they have been managed by various organisations and agencies both inter and independently, however it has been significant.

The National Weeds Coordinator compiled a database of more than 300 projects in weeds R&D since 2002. This function no longer continues.

At a regional level, the former Caring for our Country federal grants program has supported work performed in communities in cooperation with local agencies, such as catchment and land management authorities, to solve critical problems related to invasive weed spread and management. Compared with the $150–$175 million invested annually in Caring for our Country projects, weed research supported in these initiatives received only a small investment.

The challenge for location-specific grants, versus a coordinated regional or national plan, is they can lead to perverse local outcomes, for example, funding to control a weed is received downstream however funding is not granted upstream, resulting in weed replenishment downstream despite local efforts.

From 1995 to 2008, a coordinated national approach to weed research initiatives across Australia was primarily initiated and funded by organised Weed Cooperative Research Centre (CRC) investments.

Two successful weed CRCs were undertaken during this period and were funded for up to $80 million in RD&E initiatives across Australia over 14 years. Many weed scientists nationwide regarded these CRCs as the life support for weed science research in Australia.

The CRCs resulted in development of new technology and collaborative research initiatives across regions and states. They also produced highly significant extension and outreach efforts, including broad-based communications, community engagement, training workshops, seminars and programs, along with extension publications, websites and manuals.

Since the cessation of the weeds CRCs, outputs have been further developed and delivered to industry (e.g. weed CRC research underpins Meat & Livestock Australia's *Tips and Tools – Weed removers, pasture improvers*).

The Defeating the Weed Menace program was another national program established by the Australian Government during 2004 to identify Australia's most threatening weeds and to implement measures for their control. Between 2004 and 2008 the Australian Government committed $44.4 million to funding 25 Defeating the Weed Menace projects.

Recommendations resulting from the program included the following:

- Specific integration opportunities should be provided for, and facilitated in, weeds research.

- When developing new weed R&D programs, priority needs to be given to whole-systems approaches, landscape-scale perspectives and climate change impacts.
- Future weeds R&D programs should include socio-economic and institutional dimensions of weed management.
- All stakeholders jointly progress a nationally agreed information system, or process, for the collection, collation, storage and management of invasive species data and information.
- Weeds R&D programs be established with at least 4–6 year timeframes and continuity between funding cycles be planned within portfolio and budget cycles.
- Monitoring and evaluation plans are developed at the outset alongside the knowledge and adoption plan at both program and project levels.

A review of Defeating the Weed Menace also indicated:

- a need for longer-term investment and program continuity for effective weeds R&D
- the value of rigorous project selection and interactive program management in building and sustaining multi-stakeholder engagement
- the benefit of assisting researchers to develop knowledge and adoption strategies from the start of their projects
- a need to monitor and evaluate plans for both individual projects and research programs, to ensure sound data collection and reporting of projects and their impacts
- the importance of increased effort to encourage those from the broader NRM and farming systems communities to actively engage in weeds R&D funding calls.

During 2008 another national initiative rose to the forefront to support weed research and investment in Australia. Following the unsuccessful re-bid for a third weeds CRC, federal funding was allocated for a program formerly called the Australian Weeds Research Centre. A total of $15 million in research investment was distributed through this program (2008–2011) via 24 open calls and approximately 25 commissioned projects.

Impacts of complexity and fragmentation on weed RD&E

The outcome of this historically complex RD&E environment and the lack of a continuous, nationally funded weed initiative is that stakeholders across all levels of investment means – from federal and state governments to individual landholders – the cumulative benefit is not achieved over time.

This has made it difficult for research organisations, biosecurity managers, weed scientists, extension agents, local government, NRMs, community groups and producers to continue to develop both regional and national collaborative initiatives and perform longer-term projects, leading to significant research, delivery and on-ground outcomes.

Nevertheless, a number of lessons have been learned from the initiatives carried out during the preceding decades:

- There are benefits from a national approach that provides a framework for effective investment and critical mass of effort across multiple organisations in the generation of new knowledge and delivery of products to next users and end users.
- The prevention of weed seed set and containment of weed seed spread is a priority area.
- The selection and funding of federal programs simply utilises federal funds, rather than extracts efficiencies by harnessing effort (financial, human and infrastructure) of numerous interest groups, working collaboratively.
- The lack of national coordination (or large scale) in project development has led to a lack of focus for weed priorities nationally and instigated a need to refocus strategies regionally – potentially being ineffective at addressing the weed issue. A national focus enables a view on causes and not just symptoms.

The Rural R&D for Profit program

The Rural R&D for Profit program objectives clearly articulate three key needs, which directly contribute to capturing lessons from the past and addressing previous shortcomings to ensure an impact on:

- generation of knowledge, technologies, products or processes that benefit primary producers
- strengthening of pathways to extend the results of rural R&D, including understanding the barriers to adoption
- establishment and fostering of industry and research collaborations that form the basis for ongoing innovation and growth of Australian agriculture.

The *Fast-tracking and maximising the long-lasting benefits of weed biological control for farm productivity* project funded under round one of the Rural R&D for Profit program aimed to realise significant productivity and profitability improvements for primary producers by applying the above principles to one component of weed management options – biological control.

[1] Invasive Plants and Animals Committee 2017, *Australian Weeds Strategy 2017–2027*

7.2 Project, media and communications material and intellectual property

The project activity, from discovery to delivery of agents, had multiple next users. The project outputs in terms of communication products were targeted to:

- the scientific community – new knowledge/processes
- local land managers – management of agents
- stakeholders in general – opportunity from biocontrol and how to get involved; access to information; awareness of the project.

Following is a list of the outputs aggregated across next users of that information. Case studies from a range of participants in the project are documented in Appendix 7.4.4. These short stories convey a response from the perspective of a range of project partners including landholders, researchers, local government and agency managers. These have not been published but will appear in a future issue of MLA's *Feedback* magazine.

Media articles

See Appendix 7.2 attachment for content outlined below. In addition, sub-project final reports have presentations, scientific and conference papers included in Appendix 7.6.

***Fast-tracking* project**

MLA *Feedback* magazine, Aug/Sep 2016

MLA *Friday Feedback*, 26 May 2017

MLA *Friday Feedback*, 23 Feb 2018

Cylindropuntia

Day, MD 2016, Sap-sucking bug delivers coral cactus treat. *North Queensland Register*, 8 December.

Day, MD 2016, Cochineal bug doing the job on coral cactus. *Queensland Country Life*, 6 December.

McConnachie, AJ, Jones, PK and Day, MD 2017, Biocontrol of Boxing Glove Cactus: A knockout Success, *A Good Weed* (NSW Weed Society newsletter), Spring 2017, Issue 79.

Gorse

Grampian Ag News, 22 February 2018, Moths set flight in the war against problem gorse.

MLA, 23 February 2018, Moths set flight in the war against problem gorse.

WIN TV, 14 February 2018, https://www.facebook.com/pg/WINNewsBallarat/posts/

Parkinsonia

Media release 2016, Queensland Department Agriculture and Fisheries, Very hungry caterpillars join Queensland's bug army to fight pest weeds.

Newsletter post, September 2016, Dawson Catchment Coordination Association.

Undated 2016, Fitzroy Basin Association, Case Study: Reducing the spread – treating Parkinsonia has broad benefits.

October 2016, Ministerial Release, TheSourceNews.com.

Videos

Gorse – YouTube videos – Agriculture Victoria (https://youtu.be/IHP4JzUYfAw) and Adelaide and Mount Lofty Ranges NRM (https://youtu.be/pdxTVg_a-GY).

Parkinsonia – Release video currently in approval process.

7.3 Equipment and assets

No assets or equipment were acquired during the period covered by the project.

7.4 Evaluation

Evaluation of the project occurred at four levels:

- Collation and review of deliverables (see 7.4.1 Appendix attachment)
- Benefit–cost analysis (see 7.4.2 Appendix attachment)
- Project participant survey (see 7.4.3 Appendix attachment) – this comprised those closely involved in the project and others who may have participated in only one sub-project and then a component of that project (e.g. local government)
- Case studies from project participants (see 7.4.4 Appendix attachment) – providing commentary from a perspective of a producer, researcher and local government.

7.4.1 Collation and review of deliverables

A collation and review of deliverables from the sub-project log frames, against Rural R&D for Profit program objectives, can be found within the additional attachment for the Appendix 7.4.1 report.

The *Fast-tracking* project has:

- executed a wide range of biocontrol projects with encouraging results
- successfully engaged a wide range of community groups with worthwhile relationships built between researchers, producers and community groups facilitated by training and monitoring events at agent release sites
- indicated that as biocontrol takes time, the encouraging results of impact, so far, need continued monitoring into the future to show the true worth of the project

- showed the development of the biological hub to house biocontrol project results and the partnership model developed in NSW will be valuable tools for developing, managing and recording future projects in this area.

7.4.2 Benefit–cost analysis

This report presents the results of a benefit–cost analysis (BCA) of the *Fast Tracking* project. The full report is found in Appendix 7, attachment 4.2.

Executive Summary

Methods

The project was first analysed qualitatively using a logical framework, which included project objectives, activities and outputs, and actual and potential outcomes and impacts. Impacts were categorised into a triple-bottom-line framework. Principal impacts were then valued.

Benefits were estimated for a range of timeframes up to 30 years from the last year of investment in the project. Past and future cash flows during 2017/18 dollar terms were discounted to the year 2017/18 (last year of investment) using a discount rate of 5% to estimate the investment criteria.

The BCA was conducted according to the Impact Assessment Guidelines of the Council of Rural Research and Development Corporations (CRRDC, 2014).

Impacts

The investment in the *Fast-tracking* project has provided a range of agents for the control of *Cylindropuntia* spp., gorse, parkinsonia and parthenium weed. These biocontrol agents are expected to deliver more profitable grazing over the next 30 years.

Given the counterfactual scenario assumed, total funding from all sources for the project was approximately $4.48 million (present value terms). The value of total benefits was estimated at $13.91 million (present value terms). This result generated an estimated net present value (NPV) of $9.44 million, a benefit–cost ratio (BCR) of approximately 3.1 to 1, an internal rate of return of 16% and a modified internal rate of return of 9%.

Sensitivity analyses carried out on key variables used in the valuation of impacts indicate that, even with conservative assumptions, results remain positive.

The major impacts identified were of a financial and economic nature. However, some social and environmental impacts were also identified but not valued. It is expected primary producers will be the principal beneficiaries of the investment.

7.4.3 Survey of program participants

To generate evidence of the conduct of the project and its short-term deliverables, a survey was distributed among those who were both intimately and loosely connected with the project to determine a range of perspectives on the project and biocontrol.

There is an implicit bias in such a survey, however responses were solicited from a diverse breadth of sources. These included those who benefited directly from project funding (e.g. the researchers and their organisations), as well as local government staff who had some contact with the release sites, community groups that assisted with agent collection or redistribution, and landholders who hosted or enabled a release site.

The survey found the level of understanding of the project and its overall aims varied between participants. However, the survey also sought to illicit their views on how the project activity (biocontrol) may influence their activities and desired outcomes, access to information and networks, and commentary on the implementation model compared with the past decade.

Summary of survey

The 86 participants in the end-of-project survey contributed across all eight sub-projects. The respondents included one-third from local government, 20% researchers and 20% producers or community group members. The remainder were extension-based people, community group employees and agribusiness. Generally, there was little discernible difference in responses from each occupation unless mentioned.

Eighty per cent had weed management as a key part of their role and half that number were significantly involved in this project. More than half the organisations were not previously significantly involved in biocontrol.

Notwithstanding recognised variation in respondent knowledge of specific project deliverables, the expectation of respondents was that the project **aimed** to improve biological control by increasing biological agents (68%) and by generating and disseminating knowledge (52%) but less so by improving methods and protocols (36%). When asked **did the project deliver** on those same areas, the corresponding percentages were 51%, 28% and 55% respectively. That is, respondents considered the project had largely **delivered** on their expectations.

When asked about access to new resources from the sub-projects, about half thought this was significant, but producers were generally less convinced. Again, half felt they had access to technical skills not previously available, while close to two-thirds believed they had access to new networks and contacts.

When asked whether their involvement had led to a significant increased awareness and understanding, 60% agreed, with a slightly higher rating for local government employees. A similar percentage felt the project had significantly increased their linkages while half felt their skills and knowledge was up significantly.

When asked about whether biological control could reduce costs of control and increase efficiency of their business, about half indicated it could significantly.

Forty per cent of respondents felt that on-farm biological agents had increased, but only 13% felt it had been responsible for reduced weed competition. Both reduction in weed density and improved farm yield was rated ‘significant’ by 20%. Only a small proportion saw a reduction in weed control costs. The ‘no’ and ‘not sure’ answers were between 25–45% for this bracket of questions.

Two-thirds of survey respondents felt highly rewarded by their involvement in this project.

When asked about impact of this project on their organisation or weed research and development procedures or policy, 40% felt it would impact significantly on their own organisation, but only a quarter felt it would impact on weed RD&E.

A little fewer than half of the respondents felt the project provided better processes to significantly increase knowledge, deliver better resources and collaborations than they had experienced for the previous 10 years.

The full report can be found in Appendix 7.4.3 attachment.

Free text comments

When asked for extra comments, 38 out of 40 respondents gave positive responses, often with a view towards what issues need future action in biocontrol. Many mentioned the benefits of new networks or their admiration for the work of a specific person.

One-third mentioned that biocontrol takes time, maybe 5–10 years to show real results, and that it is early days in seeing the response to distribution of agents. One negative comment mentioned this was a small awareness-raising project, while another raised concerns about the location of a nursery for biological control.

Survey responses

Question 17: Do you have any comments you would like to provide about this project?

Answered: 40 Skipped: 46

“It is refreshing to encounter enthusiastic and dedicated people who are willing to share their knowledge and patience with individuals who are just beginning to understand the complexities of pest weeds and their potential impact on our environment.” Queensland local government

“The control used by us was prior to my employment, however I have noted it’s spread and transferred it to another site. We are currently looking into agents for several weeds.” NSW local government

“I participated in numerous community forums in which Raelene Kwong gave talks about the blackberry biocontrol project and found the information very informative.” Community group

“Biocontrol program still in early stages – agents yet to fully establish and move off trial release sites, which explains some of the responses. Good initiative needs time to have impact across PW infestation.” Regional NRM body

“The gorse and Biocontrol Portal sub-projects have been beneficial in enhancing the delivery of biocontrol agents to farmers and Landcare groups. The Biocontrol Portal has helped to map established biocontrol agents and is a great resource to assist community groups in accessing information about what agents are available and where to find them. The silverleaf nightshade sub-project did not deliver any on-ground results but was able to use improved techniques and tools to assess the safety of a prospective agent.” Victoria State Government

“Blackberry control by traditional means is unsustainable. Community collaboration and science together offer our best hope to reduce ecological damage from this weed and the consequences of our current approach. It has been very rewarding to see increased research starting to occur and pathways to success identified. We now need a persistent continuing effort to establish a strategic, collaborative approach to supporting affected communities, adequately funding ongoing research and husbanding existing biocontrol agents to extract the most benefit from them. I commend the MLA for supporting this work.” Community group

“Biocontrol in our situation is limited by the scattered growth of weeds over a very large area. We only used it on an isolated infestation of Tiger Pear covering approx. 2ha.” Queensland local government

“The program is a trial and it is a long term solution so population and density questions reflect the fact that it’s in its early stages.” Community group

“Please continue to improve biocontrol agents as we desperately need help to fight these rapidly spreading noxious weeds as they are sadly winning the battle.” Landholder

“Weed Biological Control is a long term process and the results of this project won't become evident for many years, at least until the released agents become widely established. Therefore, many of these questions were not possible to answer with any certainty.” Industry

“I recently attended a meeting where Raelene Kwong spoke about her blackberry bio control research work and was pleased to see a possible future for further bio control development to complement agents already available.” Community group

“Impact of the bio agent has been difficult to determine therefore the net benefit from the project is difficult to quantify. Potentially more time is required to allow populations of the bioagent to adapt and impact on the target species.” Queensland State Government

“Need more $ to control blackberry's, crown land is a mess.” Landholder

“We have worked with Dr Raelene Kwong to spread available biocontrols for pest plants such as St John’s Wort, Paterson’s Curse, Gorse, English Broom, Spear Thistles and Blackberry. Sometimes with dramatic effect over time, for example Paterson’s Curse around Tallangatta, the hills are no longer purple. There are many more significant pest plants and animals (Rabbits – they will be back) whose control would benefit from a vigorous biocontrol research program.” Community group

“Bio control is very necessary in management of pest weeds.” Community group

“As yet no new biocontrols introduced for blackberry, but the community forums and information provided by Raelene Kwong have improved local understanding of blackberry biocontrol options and opportunities, resulting in some community groups actively seeking further information and actions for blackberry biocontrol. This has been very useful and likely to have major impact.” Regional NRM body

“This project has enabled a number of landholders to be the nursery sites for a valuable contribution towards managing gorse in the area. Some sites are too difficult or dangerous to access and the landholders are looking at biological control methods as another arrow to the bow in management.

The team from AgVic were an absolute pleasure to work with, and our Landcare network appreciate being able to participate in the project and be part of such valuable works." Community group

"Controlled specificity testing in this project identified non-target host use by control agent, avoiding a catastrophe if agent was released in this country. This evidence based outcome is of great significance to international agencies that were similarly planning use of the agent for control of the weed in overseas countries." NSW State Government

"I really appreciate the effort from BQ Officer Jason Callander. The Most promising biocontrol program I have been involved in my 13 years. I would have liked to have put more time into the project however I was unable due to my employer and other work commitments." Queensland local government

"This project did not end up delivering biocontrol agents to landholders therefore no improvements to on-farm weed management were possible. Nevertheless the project was still successful from a scientific perspective." Victorian State Government

"The import agent that I am involved with has failed in the host range testing, which means that it is less likely to be released in Australia despite great success overseas." NSW State Government

"Small awareness raising project with respect to biocontrols." Regional NRM body

"The project has allowed us to bring an endemic weed under management and this will be reflected in our Biosecurity Plan. Jason Callandar was excellent in teaching myself and LPO's about bio-control for Parthenium, how to spot it, collect it and move it around the region." Queensland local government

"We need to know of any adverse effects on our commercial crops of *Solanum Centrale, S.Chippendaleai* and *S. Cleistogamum*." Industry

"The people involved were extremely dedicated and helpful, and also a fund of information which they shared generously." Landholder

"There is significant value in continued research and trials associated with bio-control agents." Community group

"I have a problem with SWNRM using the town common at Wyandra as a breeding ground for the biological control agent. Landowners currently use the common for livestock agistment and my problem is that the stock are moving off to be sold without holding them for a period of time so any seed or material may be passed. Another problem this practise is a nice to attitude meaning there are no records or accountability regarding landowners obtaining the control agent from the common. I intend to implement a surveillance program and expect that this will be a common landowners example that they are meeting their General Biosecurity Obligation." Queensland local government

"Keep up the good work and we just might be able to get on top of the problem in the future." Queensland local government

“Hopefully research into Blackberry controls can continue so we might see another tool we can use in the near future.” NSW State Government

“It was a fantastic project to be involved in!” Regional NRM body

“There are many factors that contribute to exotic plant species becoming invasive and this may take multiple decades to occur before it is targeted for control. It’s impractical and unrealistic to expect a halt in spread or any significant retraction in a weed’s infestation, effected by biocontrol agents, within a fraction of the time it took to become problematic. At its very best, biocontrol can be very impactful within a decade across many infestations but, rarely so across the entire distribution of the weed. It is but one tool in a suite used to exert some form of physical pressure(s) on a weed’s capacity to propagate and spread. It’s usually self-perpetuating, low cost compared to other control measures (herbicides, mechanical, fire, manual etc.), it spreads naturally across the landscape to where ever the weed is established and has far less negative impact to the surrounding environment. At its poorest, biological control can assist in slowing the ongoing spread &/or density of the weed through its impact on recruitment, seed production/survival &/or plant vigour. As such, a temporal awareness and clear understanding is imperative in the evaluation of and in determining whether biological control has been successful or not.” Commonwealth Government

“Increased application in regions with greater infestations of Cylindropuntia spp. It has been of some assistance to our region.” Regional NRM body

“This project has not only considerably advanced the knowledge of impact of cochineal biotypes on specific species of cactus, but has made that knowledge and the agents available widely in WA thereby advancing the control of these cacti in areas where chemical or mechanical methods would not be cost-effective.” NSW State Government

“Having access to Cylindropuntia cochineals has opened the door to breeding populations in the SA rangelands. This will allow us to use biocontrol more widely and less herbicides. There are also massive time and resource benefits to land managers.” SA State Government

“This project allowed very valuable networks to be built between departments and between researchers and extension staff. It outlined how research has on ground outcomes to producers. There has also been a noticeable increased awareness and enthusiasm for biological control options within the organisation. Overall, great outcomes on ground, and great outcomes socially.” NSW State Government

“Weeds Never Sleep or is that Rust?” NSW State Government

“There were quite a few questions that were not relevant to me so I have left them blank. I have only worked with community engagement in Hudson pear. It is too early to rate the success of this agent yet.” NSW State Government

7.4.4 Case studies

Case studies have been completed as part of this project. The content has been created for communication and evaluation activities.

The full suite of case studies is in the Appendix 7.4.4 attachment.

7.5 Budget

A statement of funds and contributions received and spent over the life of the project will be provided upon completion of the project.

A summary statement of the budget for the life of the project is below.

Table 5. Summary budget

Summary		Notes
Total cash budget	$2,846,859	Grant + MLA cash + other cash
Spend to 11 June 2018	$2,262,563	Milestone 6 payments (sub-contract final reports) are not included in this figure, nor a final payment (to MLA's sub-contracted projects). This will be done following feedback from the DoWAR on the final report and if additional work is required.

7.6 Sub-project reports

A Final Report has been provided by each of the sub-projects of the project and can be found in Appendix 7.6.1–7.6.8. These reports expand on the information provided throughout this report in much greater detail.

7.6.1 Partnership model
7.6.2 Blackberry
7.6.3 Cylindropuntia
7.6.4 Gorse
7.6.5 Parkinsonia
7.6.6 Parthenium
7.6.7 Silverleaf nightshade
7.6.8 Biocontrol Hub and app

7.7 References

Page, AR and Lacey, KL 2006, *Economic impact assessment of Australian weed biological control*. Prepared by the AEC group for the CRC for Australian Weed Management.

Palmer, WA, McLaren, D and Sheppard, AW 2014, *Australia's present scientific capacity to progress the biological control of weeds.* In 'Proceedings of the XIV International Symposium on Biological Control of Weeds', 2–7 March 2014, University of Cape Town, South Africa, pp. 183–186. Eds Impson, FAC, Kleinjan, CA and Hoffmann, JH.