final report

Project code: WBC.0050

Prepared by: Greg Lefoe (Agriculture Victoria), John Ireson and Richard Holloway

Date published: 30 July 2018

PUBLISHED BY
Meat and Livestock Australia Limited
Locked Bag 1961
NORTH SYDNEY NSW 2059

Biological control of gorse

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Plain English Summary

Gorse, *Ulex europaeus* L., is a Weed of National Significance and one of the most invasive weeds in south-eastern Australia. The annual cost of gorse management to Australian agricultural and forest industries in 2000 was estimated at $7 million. The difficulty and expense in controlling gorse has resulted in biocontrol options being investigated. The gorse soft shoot moth shows considerable promise as a natural control of the weed, but its distribution is mostly limited to Tasmania. To help the moth establish and spread, more than 25,000 gorse soft shoot moths were collected from Tasmanian sites where it is abundant, and released by farmers, land managers, scientists and community volunteers in four States. Monitoring of release sites across south-eastern Australia provided valuable information on factors such as plant condition and rainfall, that help the moth survive and flourish. Further research into the combined impact of insects and naturally occurring fungi are recommended following observations of plant death. These efforts provide the best chance of providing long-term sustainable management of gorse infestations in Australia.

Figure 1. Collecting gorse soft shoot moth at Melton-Mowbray, Tasmania for redistribution to Victoria, New South Wales and South Australia (14 February 2017) (Photo: Raelene Kwong).

Executive summary

Gorse, *Ulex europaeus* L., is a Weed of National Significance (WoNS) and one of the most invasive weeds in south-eastern Australia. Gorse occurs across 23 million hectares of Australia's land mass and infests up to 1 million hectares within that area. The annual cost of gorse management to Australian agricultural and forest industries in 2000 was estimated at $7 million. Gorse management is difficult because the weed is a prolific seeder, and regular follow-up treatment over many years is needed to gradually deplete the long-lived soil seedbank. The difficulty and expense of long-term management resulted in biological control options being investigated.

Four biological control (biocontrol) agents of European origin have been released in Australia. The gorse seed weevil and the gorse spider mite are established across south-eastern Australia. The gorse thrips is widely established in Tasmania and starting to spread in Victoria and South Australia. Recoveries of gorse soft shoot moth in Tasmania suggested this species, the subject of this project, would also establish in Australia. However, gorse soft shoot moth populations remained small and vulnerable to extinction in mainland States. This project monitored previous release sites in Tasmania to identify sites that might be suitable for collecting agents for redistribution to new sites, or to supplement previous releases. Well-timed and carefully targeted redistribution activities were proposed to (1) supplement previous releases and improve establishment success, especially in mainland States of Australia where gorse soft shoot moth was vulnerable to extinction, and (2) target new areas where gaps in biocontrol agent distribution existed. To ensure redistribution activities in this project had maximum effect, areas within the WoNS containment zone were prioritised for new releases, and producers, land managers, and on-ground networks within those zones were targeted for engagement activities. The success of this approach was demonstrated by the achievement of key objectives of the project, listed below:

1) *Collect gorse soft shoot moth (GSSM) from sites in Tasmania where the agent is established.*

   Achieved. More than 25,000 gorse soft shoot moths were collected from Tasmanian sites where it is abundant.

2) *Introduce GSSM at a minimum of 20 new sites across gorse-infested regions of Victoria and a minimum of 2 new sites in South Australia.*

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

3) *Address gaps in agent distribution by introducing GSSM at a minimum of 18 new sites in Tasmania.*

   Exceeded. 24 new releases were conducted in Tasmania to address distribution gaps in that State.

4) *Monitor 8 existing release sites in Victoria and 8 existing release sites in Tasmania (at least once in the first two years of the project), to determine agent establishment, spread*

and abundance. Assess suitability of each site for agent collections, and where applicable, collect data on agent impact.

Exceeded. Monitoring for agent establishment, spread and abundance was conducted at 8 existing release sites in Victoria, and 75 existing release sites in Tasmania (67 more sites than the target of 8). Sites with the highest population densities that were suitable for collections were located in the Tasmanian midlands at Jericho and Melton Mowbray. At the 31 Tasmanian sites where the agent was recovered, populations have permanently established and are spreading at 19 (61.0%) of these, and were recovered around the release point at another 12 (39.0%) sites ("permanently established" indicates that the agent has survived at the site for at least 1 year and is spreading from the release point). Gorse soft shoot moth has now spread over at least 450 sq. km. in an area between Kempton and Oatlands, Tasmania.

5) *Monitor (at least once in the life of the project) 12 new release sites in Victoria and 12 new release sites in Tasmania, to confirm establishment of the agent.*

   Exceeded. 14 new release sites were monitored in Victoria and 14 new release sites were monitored in Tasmania.

6) *Monitor 9 existing sites in South Australia (three sites each year of the project) to determine agent establishment, spread and abundance. Assess suitability of each site for agent collections, and where applicable, collect data on agent impact.*

   Exceeded. Despite a delay at the beginning of the project, there were 16 monitoring events conducted at existing sites in South Australia.

7) *Capture and analyse establishment data and local knowledge to improve biocontrol success.*

   Achieved. Establishment data, especially from Tasmanian sites, informed the selection of new release sites based on rainfall, shading and gorse condition. Releasing 500 larvae was found to be as effective as releasing 100 adults, but collecting larvae required fewer resources and less training.

8) *Develop best practice recommendations to integrate biocontrol into production systems.*

   Achieved. Content for an updated Gorse Weed Management Guide was drafted. The existing Gorse Weed Management Guide was published in 2003, before the introduction of gorse soft shoot moth to Australia. The 2018 revision adds information on gorse soft shoot moth and integrated management, including 1) gorse soft shoot moth collection, release and monitoring advice developed in this project, 2) information on the Biocontrol Hub, and 3) updated links and contacts.

9) *Deliver 6 field days/workshops in Victoria and 6 field days/workshops in Tasmania.*

   Exceeded. More than 19 field days and workshops delivered in Victoria and Tasmania.

10) *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.*

Achieved. Content for an updated Gorse Weed Management Guide was drafted. As stated previously, the existing Gorse Weed Management Guide was published in 2003, before the introduction of gorse soft shoot moth to Australia. The 2018 revision adds information on gorse soft shoot moth and integrated management, including 1) gorse soft shoot moth collection, release and monitoring advice developed in this project, 2) information on the Biocontrol Hub, and 3) updated links and contacts. In addition to requirements, significant progress was made on the development of a Bayesian Belief Network (BBN) to capture monitoring results and expert opinion of the factors that favour gorse soft shoot moth establishment. The BBN will be submitted for publication in the second half of 2018, and will provide a process model for predicting outcomes of actions based on current knowledge (usually qualitative), with a view to updating the model with data as monitoring data becomes available.

An important additional finding from monitoring was the observation of plant death at sites where agents are established. It is speculated that feeding by gorse biological control agents, particularly the gorse soft shoot moth, can increase susceptibility to attack by naturally occurring fungi, and this may become a significant factor in suppressing the spread of gorse in the future.

It is therefore recommended that future research and extension activities:

1. Investigate the potential contribution of naturally-occurring plant pathogens to gorse biological control, apparent associations with introduced insect agents, and long-term impacts of biological agents on gorse populations,
2. Encourage ongoing monitoring of new sites through producer and land manager networks, especially use of the Biocontrol Hub app to capture and share monitoring results,
3. Promote the continued redistribution of gorse soft shoot moth across south-eastern Australia once the agent becomes abundant at mainland sites. This could be achieved efficiently by supporting on-ground networks, such as Landcare, and exploiting the monitoring and engagement potential of the Australian Biocontrol Hub web-site and app.

Figure 2. Adult gorse soft shoot moth (left) and larva (right) (Photos: Wade Chatterton).

Table of contents

Figures

Tables

1 Project rationale

Gorse, *Ulex europaeus* L., is a Weed of National Significance (WoNS) and one of the most invasive weeds in south-eastern Australia. Gorse occurs across 23 million hectares of Australia's land mass and infests up to 1 million hectares within that area. The annual cost of gorse management to Australian agricultural and forest industries in 2000 was estimated at $7 million (Anon 2006). Gorse management is difficult because the weed is a prolific seeder, and regular follow-up treatment over many years is needed to gradually deplete the long-lived soil seedbank. The difficulty and expense of long-term management resulted in biological control options being investigated.

1.1 Biological control options

Four agents of European origin have now been released in Australia. These are the gorse seed weevil, *Exapion ulicis* (Forster) released in 1939, the gorse spider mite, *Tetranychus lintearius* Dufour released in 1998, the gorse thrips, *Sericothrips staphylinus* Haliday released in 2001 and the gorse soft shoot moth, *Agonopterix umbellana* (Fabricius), released in 2007 (Ireson et al. 2013). The gorse seed weevil and the gorse spider mite are established across south-eastern Australia. The gorse thrips is widely established in Tasmania and starting to spread in Victoria and South Australia (Ireson and Davies 2012). Recoveries of gorse soft shoot moth in Tasmania suggested the species would also become widely established in Australia. However, gorse soft shoot moth populations remained small and vulnerable to extinction in mainland States (Ireson et al. 2013; Ireson & Holloway 2014). In Tasmania, gorse soft shoot moth became well established at its first release site in the midlands at Lake Tiberias near Jericho, where high larval densities have been recorded since December 2011 (Ireson et al. 2013). High population densities were also recorded at Melton Mowbray, Tasmania, where releases were first conducted in 2012. These sites were therefore ideal for collecting agents for redistribution to new sites, or to supplement previous releases.

1.1.1 Benefits of a targeted redistribution program

Well-timed and carefully targeted redistribution activities were proposed to (1) supplement previous releases and improve establishment success, especially in mainland States of Australia where gorse soft shoot moth was vulnerable to extinction, and (2) target new areas where gaps in biocontrol agent distribution existed. In doing so, redistribution could accelerate the spread and establishment of gorse soft shoot moth across gorse-infested areas of south-eastern Australia, and bring forward the economic and environmental benefits of biological control by many years. To ensure redistribution activities in this project had maximum effect, areas within the WoNS containment zone (**Error! Reference source not found.**) were prioritised for new releases, and producers, land managers, and on-ground networks within those zones were targeted for engagement activities.

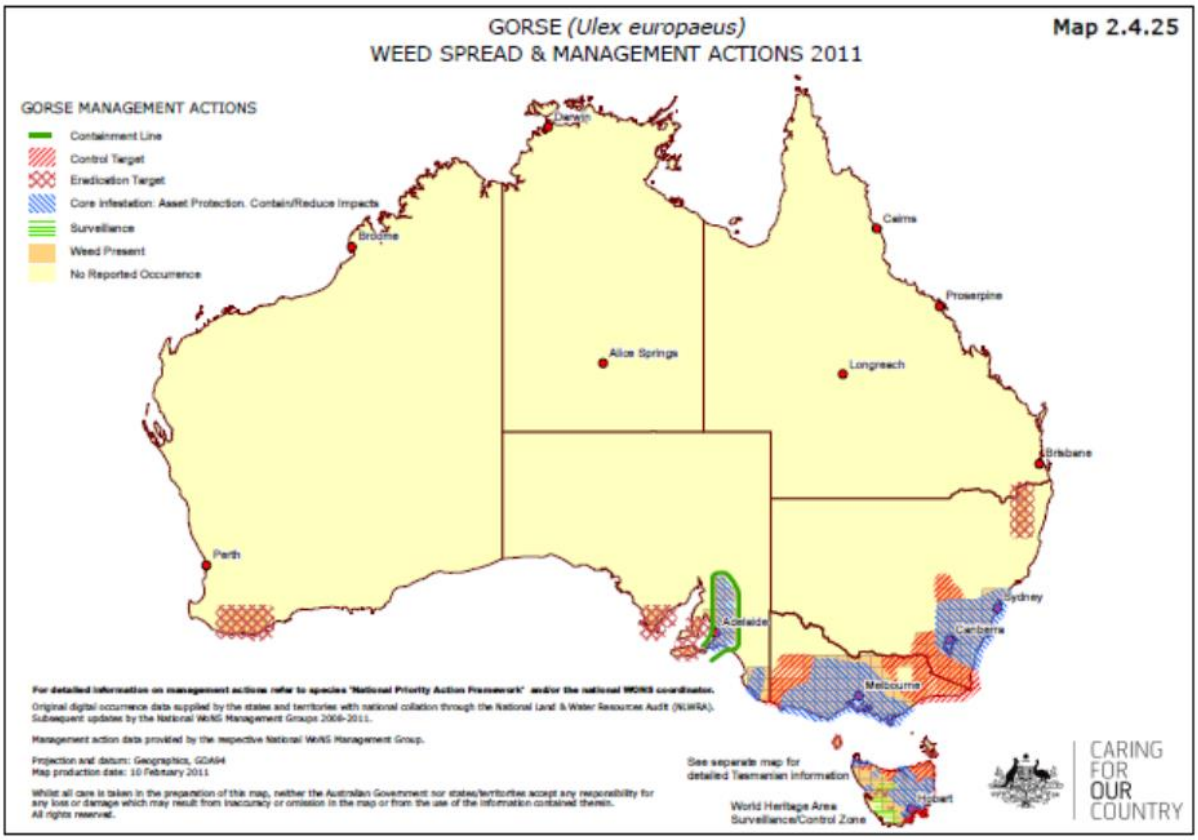


Figure 3. Gorse management zones as of 2011 (http://weeds.ala.org.au/WoNS/gorse/)

1.2 Timing biological control activities

Life cycle studies that were conducted at Jericho between October 2011 and February 2013 showed the life cycle of gorse soft shoot moth was univoltine (Ireson et al. 2013). Larvae first commenced hatching in October and mature (6th instar) larvae were present by December. Adults emerged in high densities by the beginning of February but did not commence egg-laying until late winter (Ireson et al. 2013). It was therefore evident that the best options to redistribute gorse soft shoot moth across gorse-infested areas of south-eastern Australia were to:

1. collect and re-release larvae that were approaching maturity and let them complete their pupation and overwinter as diapausing adults, or
2. collect and redistribute the newly emerged diapausing adults.

The final report for work conducted by this sub-project from 2015 to 2018 presents the results of surveys for population establishment and dispersal at previous release sites, together with the results of a targeted redistribution program that utilised field-collected gorse soft shoot moth larvae and adults.

2 Project objectives

By 01 September 2018:

1) Collect gorse soft shoot moth (GSSM) from sites in Tasmania where the agent is established.

2) Introduce GSSM at a minimum of 20 new sites across gorse-infested regions of Victoria and a minimum of 2 new sites in South Australia.

3) Address gaps in agent distribution by introducing GSSM at a minimum of 18 new sites in Tasmania.

4) Monitor 8 existing release sites in Victoria and 8 existing release sites in Tasmania (at least once in the first two years of the project), to determine agent establishment, spread and abundance. Assess suitability of each site for agent collections, and where applicable, collect data on agent impact.

5) Monitor (at least once in the life of the project) 12 new release sites in Victoria and 12 new release sites in Tasmania, to confirm establishment of the agent.

6) Monitor 9 existing sites in South Australia (three sites each year of the project) to determine agent establishment, spread and abundance. Assess suitability of each site for agent collections, and where applicable, collect data on agent impact.

7) Capture and analyse establishment data and local knowledge to improve biocontrol success.

8) Develop best practice recommendations to integrate biocontrol into production systems.

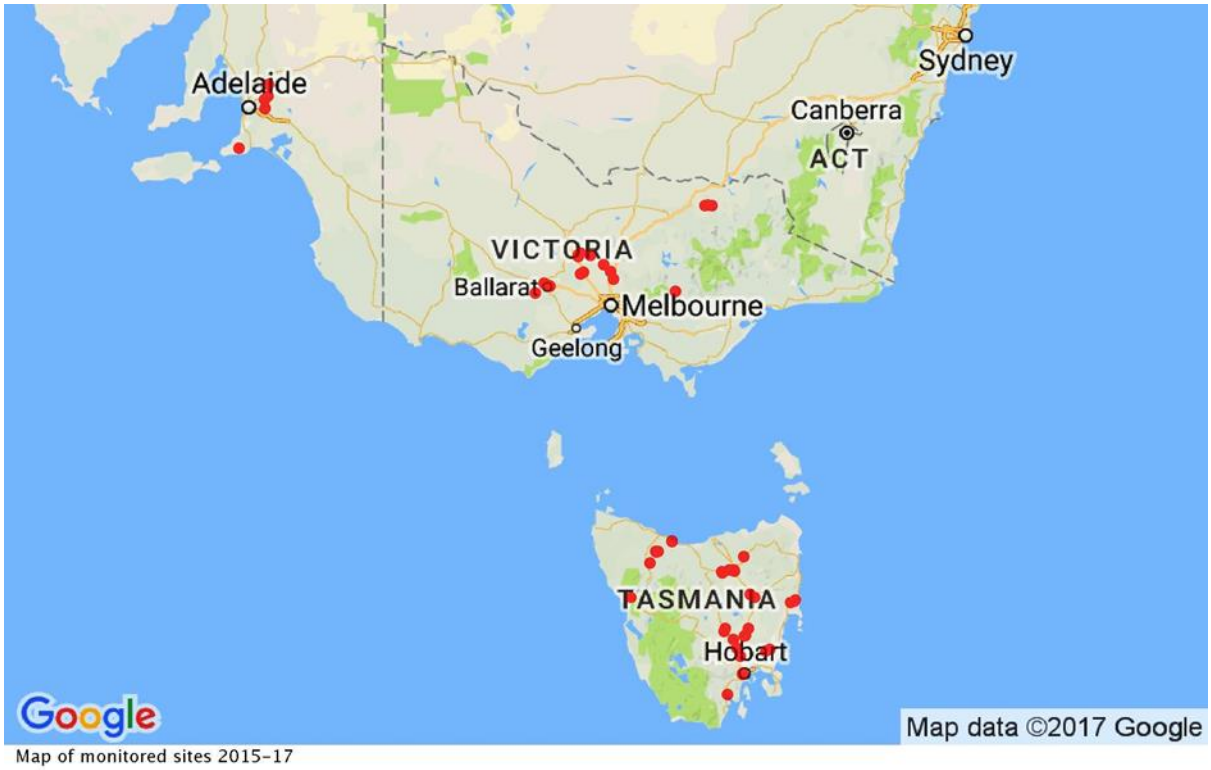
9) Deliver 6 field days/workshops in Victoria and 6 field days/workshops in Tasmania.

10) 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.

3 Method and project locations

3.1 Monitoring for establishment of gorse soft shoot moth (Objectives 4, 5, 6 & 7)

Monitoring of past release sites in Tasmania, Victoria and South Australia (**Error! Reference source not found.**4) was conducted to determine the number of sites where gorse soft shoot moth was established, and which of those sites were suitable for agent collections. Monitoring protocols were standardised 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. The late-larval stage was selected for monitoring because webbing produced by larvae on branch tips was easier to detect than adult moths when populations were small (**Error! Reference source not found.**5 and **Error! Reference source not found.**). If larvae were located, dispersal around the central release point was traced by checking gorse bushes every 50, 100, 250, 500 m or beyond until no larvae could be detected.



Map of monitored sites 2015–17

Figure 4 Gorse soft shoot moth sites monitored in Tasmania, Victoria and South Australia between 2015 and 2017.

Figure 5 The gorse soft shoot moth adult (centre of image) is well camouflaged and difficult to detect when populations are low.

Monitoring for agent establishment, spread and abundance was conducted at 8 existing release sites in Victoria (22 and 23 December 2015), and 75 existing release sites in Tasmania (67 more sites than the target of 8).

The Tasmanian surveys were conducted between 6 and 20 December 2015 (25 sites), 6 and 18 December 2016 (27 sites) and between 30 November and 7 December 2017 (23 sites) (Attachment 1). The suitability of each site for agent collections was assessed, and where applicable, data on agent impact was also collected **(Objective 4)**.

The large number of Tasmanian sites monitored through this project provided an opportunity to capture and analyse establishment data and local knowledge to improve biocontrol success **(Objective 7)**. Data from surveys conducted between 2015 and 2017 were combined with results obtained from earlier surveys conducted in December 2014. At sites where permanent establishment was recorded, the result of releasing either adults or larvae without any cage restraint was compared to see if there were differences in establishment success based on release method. Release sites that may have been affected by adverse conditions, such as bad weather, were not included in the comparison, and any influence of these factors was therefore removed. A preliminary investigation was also conducted on other factors influencing establishment, including rainfall, temperature, site aspect and shading. Rainfall and temperature data from weather stations nearest release sites was obtained from the Bureau of Meteorology website (http://www.bom.gov.au/climate/data/).

In South Australia, monitoring was conducted twice for each of 8 sites between 2015 and 2018 (i.e. 16 monitoring events) **(Objective 6)**.

3.2 Redistribution

3.2.1 Collection, consignment and release of larvae (Objectives 1, 2 & 3)

Larvae approaching maturity are easily seen and collected because they form webbed shelters near the branch tips of new gorse growth (**Error! Reference source not found.**). Larvae-infested branches were collected using a pair of secateurs and appropriate personal protective equipment and clothing. Infested branch tips were placed in large insulated plastic containers ('Eskie type') containing freezer blocks to reduce larval activity (**Error! Reference source not found.**). They were then transported to the new release sites within two days of collection.

Figure 6. An insulated container with gorse soft shoot moth larvae for release. Webbing produced by gorse soft shoot moth larvae is clearly shown.

At least 500 larvae were released per site with releases conducted by lodging infested branches into the gorse.

Enough infested branches were air freighted to Victoria to enable six releases at Victorian sites in December 2015 and 2016 and four in December 2017. For the 2015 releases, larvae were sent in two separate consignments with each containing enough larvae for three releases. Larvae were field collected on 7 and 14 December respectively and, in each case, consigned the following day. Larvae infested branches were placed in six plastic containers (29 × 20 × 18 cm) (length × width × height). For transport, two of these plastic containers were then placed side by side inside a polystyrene box (57.0 x 38.0 x 33.0 cm) (length × width × height) with freezer blocks to keep the larvae cool. For the 2016 and 2017 releases, infested branches were field collected on 5 December and 29 November

respectively, placed directly into polystyrene boxes and consigned the following day. Each box contained enough larvae for one field release.

3.2.2 Collection, consignment and release of adults (Objectives 1, 2 & 3)

An alternative to collecting larvae was to flush adults from beneath gorse bushes using a bee smoker and capture them in an insect net or tent as they took flight (Ireson and Holloway 2014) (**Error! Reference source not found.**). Large numbers of adults were collected using this technique. This method is, however, more resource intensive than the method for collecting larvae and requires specialised equipment including a bee smoker, respirator, insect tent and fire extinguisher.

Figure 7.Collecting gorse soft shoot moth adults at Melton-Mowbray, Tasmania for redistribution to Victoria, New South Wales and South Australia (14 February 2017). Adults were flushed from gorse bushes using a bee smoker and caught in an insect tent (above left), before being collected (above right) and prepared for shipment (Photos: Greg Lefoe and Raelene Kwong).

Collections of adults for Tasmanian and mainland releases were made during field days conducted in Tasmania at the Melton Mowbray site on 9 February 2016, 14 February 2017 and 13 February 2018. In 2016 and 2017, project personnel and field officers from Victoria, South Australia, NSW and Tasmania attended the field days to make the collections (see Section 3.2.3 for a description of these field days). The biology of the gorse soft shoot moth was discussed together with collection, consignment and release techniques, and selection of release sites. Adults were air-freighted to mainland states in plastic containers. Adult activity was minimized by placing the containers in 'eskies' to which freezer blocks were added (as for larval shipments, see 3.2.1). Crumpled paper towelling placed in the containers provided a sheltered habitat. The moths were also transported to field release sites in 'Eskies', where they were gently shaken onto gorse bushes at the point of release.

For all releases (larvae and adults; **Error! Reference source not found.**) property owners or land managers were provided with detailed instruction on site management and the agent's biology at the time of release. They were also made aware of the lengthy period of at least 4-5 years before

agent populations could be expected to increase to visibly high densities (if establishment was successful) (also see Section 3.2.3 below).

Figure 8. Locations where gorse soft shoot moths were released in Tasmania, Victoria and South Australia; 2015-2017.

3.2.3 Field days and workshops (Objectives 1-10)

Field days and workshops formed an important component of redistribution and engagement activities because they contributed to each of the sub-project objectives. Specifically, they aimed to:

1. Transfer knowledge of gorse soft shoot moth 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 (individual producers, Landcare groups members, weeds contractors),
2. Involve next-users and end-users directly in biological control site assessment, monitoring, agent collection and release,
3. Ensure gorse soft shoot moth releases were integrated with local and regional weed management planning,
4. Capture observations and local knowledge of production systems, past weed management, and prevailing conditions that could impact biological control.

Field days and workshops were conducted with individuals and groups identified through existing networks (for example, Community-based Natural Resource Management groups such as Landcare),

or new contacts developed during the project. The target audience and delivery format varied according to the event's purpose (Table 1).

Table 1. Examples of target audiences at gorse soft shoot moth field days and workshops and the purpose of the events.

Purpose	Delivery format	Primary target audience
1. Assess prospective release sites; 2. Monitoring; 3. Collect agents; 4. Release agents; 5. Training and knowledge transfer.	Field day	Producers, public land managers, Community-based NRM groups
Training and knowledge transfer only	Workshop, Conference, Seminar, other (ie. Biocontrol Hub, gorse management guide)	Producers, public land managers, Community-based NRM groups, scientists, policy officers

Gorse soft shoot moth collection field days were all held in Tasmania at field sites where gorse soft shoot moth could be harvested in large numbers for redistribution to the mainland (these sites were identified in Section 3.1). These field days were organised by John Ireson and Richard Holloway and involved project collaborators from Victoria, New South Wales and South Australia.

Gorse soft shoot moth site assessments, releases and monitoring events provided opportunities for hands-on training and engagement through field days. Field days were organised to coincide with these activities if the property owner provided permission, and there was sufficient time to organise the event (agent availability, site conditions and weather sometimes disrupted planning). Field days to coincide with these activities were held in Tasmania and Victoria.

Workshops and conferences differed in that they were usually indoors (or in a tent), focused primarily on knowledge transfer, and provided an opportunity to target larger and more diverse audiences.

3.3 Collection and identification of fungi damaging gorse

Gorse foliage showing primary feeding damage from the biological control agents, particularly gorse soft shoot moth, gorse spider mite and gorse seed weevil, often showed symptoms of dieback resulting from fungal attack. It also appeared that high agent population densities and their associated feeding damage were associated with the fungal damage. Severe and widespread dieback was noted on gorse bushes during surveys at Carrick on 7 December 2017, at Bothwell on 5 December, at Melton Mowbray on 13 February 2018 and at Lymington (see Attachment 1). Infested gorse foliage was returned to the laboratory for pathogen identification using standard techniques. To obtain a pure culture, sections were sterilized in sodium hypochlorite and placed on PDA (potato dextrose agar) and PA (Pectin Agar) plates in a laminar flow cabinet and then incubated at 22ºC.

4 Results

4.1 Establishment of gorse soft shoot moth

Rate of establishment success of gorse soft shoot moth

From 81 new release sites in Tasmania, 14 have been destroyed (8 by fire, 4 cleared or mulched and two sprayed) and checks are still to be made at 22 including nine sites where the more recent releases were conducted in December and February (2016-2018). GSSM larvae were recovered from 31 (69%) of the remaining 45 sites with no recoveries at 14 (31%) of the sites. At the 31 sites where the agent was recovered, populations have permanently established and are spreading at 19 (61%) of these, and were recovered around the release point at another 12 (39%) sites ("permanently established" indicates that the agent has survived at the site for at least 1 year and is spreading from the release point). The 19 sites where the agent has permanently established are now recorded on the Weed Biological Control Portal of the Atlas of Living Australia (currently being transferred to the Biocontrol Hub).

Of the 24 new release sites in Victoria, 14 have been monitored with GSSM found to be persisting at 5 sites. Further monitoring is required at all Victorian sites as detection of gorse soft shoot moth is low in the first few years. Sites monitored in Tasmania, Victoria and South Australia (preliminary) are shown in **Error! Reference source not found.** and Attachments 1, 2 & 3.

Figure 9. From left: Local producer and Landcare member Pip Elston, and AgriBio Science & Technology interns Ha My Pham (University of Melbourne) and Nick May (Deakin University) detected gorse soft shoot moth while conducting the standardised monitoring protocol of a 10 minute search around the point of release, Baynton, Victoria.

Observations of spread and impact in Tasmania

Sites with the highest population densities were located in the Tasmanian midlands at Jericho and Melton Mowbray, where releases were conducted in 2007 and 2012 respectively. Surveys conducted in the southern Tasmanian midlands in December 2017 where these sites are located showed that the moth has now spread over at least 450 sq. km in an area between Kempton and Oatlands. High population densities of the moth are also dispersing from Bothwell in the central highlands and at Lymington in the south. The high larval densities around the release points are causing observable damage to new growth in late spring/early summer. The other three gorse biological control agents that have established in Tasmania, the gorse seed weevil, gorse spider mite and the gorse thrips are also present at these sites where many bushes are now showing visual signs of poor health, which has been exacerbated by additional attack by fungal pathogens (**Error! Reference source not found.**).

Characteristics of sites where establishment failed

Five of the 14 sites where the gorse soft shoot moth was not recovered were located at Hampshire and a neighbouring site at Guilford in northwest Tasmania (Attachment 1). Multiple releases (10) of both adults and larvae were conducted at these sites, where the mean annual rainfall is high and averaged over 1,500 mm from the time releases commenced (Attachment 1). The Hampshire sites were also close to tree lines and are shaded. Sites at Tolman's Hill and New Town are also shaded by trees. The remaining six sites where establishment was not recorded were all in close proximity to other sites where establishment has been successful and where the mean annual rainfall ranged from 440 – 667 mm since the time of release. However, at all six sites the condition of the gorse was poor and showed a lack of new spring growth when the agent was released. Furthermore, in all cases the releases where followed by either one or two years of below average rainfall in 2014 and 2015 which further restricted the ability of the gorse to produce new growth.

Monitoring of eight existing sites (pre-2015) in Victoria found establishment at 1 site, no recovery at 4 sites, and 3 sites had been destroyed (Attachment 2). The poor rate of establishment at older sites in Victoria may also be attributable to poor condition of gorse at the time of the releases (drought affected).

Influence of life-stage released

There was no evidence from the available data that establishment success is increased by collecting and releasing adults in late summer/autumn as opposed to collecting and releasing larvae in early summer. In Tasmania, 14 sites have become permanently established ('A sites') from open releases of either adults (seven sites) or larvae (seven sites) (Attachment 1). The other five established sites resulted from releases of both adults and larvae and in some cases the releases were caged.

Integrating biocontrol into production systems

Knowledge obtained through monitoring and producer feedback was incorporated into a draft update of the WoNS Gorse Weed Management Guide (Attachment 10). The existing Gorse Weed Management Guide was published in 2003, before the introduction of gorse soft shoot moth to

Australia. The 2018 revision adds information on gorse soft shoot moth and integrated management, including 1) gorse soft shoot moth collection, release and monitoring advice developed in this project, 2) information on the Biocontrol Hub, and 3) updated links and contacts. The Department of Environment and Energy is currently transferring responsibility for this and other WoNS management guides to the new Centre for Invasive Species Solutions (CISS). The CISS will publish the updated guide for gorse pending review and appropriate approvals. Once it is published and uploaded, the Gorse Weed Management Guide will ensure extension materials accessible on the Biocontrol Hub are up-to-date **(Objectives 8 & 10)**.

Figure 10. Extensive dieback of gorse at Melton Mowbray, Tasmania, where gorse soft shoot moth, gorse spider mite and gorse seed weevil are established (Feb 2018). The fungus Paraconiothyrium sp. was identified on affected plants at this site.

4.2 Redistribution of gorse soft shoot moth

In Tasmania, eight larval releases were conducted in December 2015 and one adult release in February 2016. There were seven larval releases in December 2016 and two adult releases in February 2017. In November/December 2017 there were four larval releases followed by two adult releases in February 2018. Overall, 123 releases at 81 different sites have now been conducted in Tasmania since the agent's first release in 2007 (Attachment 1). Larval infested foliage was collected and consigned to Victoria to enable six releases in December 2015 and 2016 respectively and four releases in December 2017. At a 2016 field day, 1,000 adults were collected to enable six field releases in South Australia (100-200/site). 800 adults were collected for four releases in NSW (200/site) (partly funded by a separate Australian Government NRM project). A 2017 field day enabled the collection of ca. 3,875 adults which resulted in ca. 1,275 adults released at ten sites in South Australia (75-200/site), 1,800 moths for release at 12 sites in NSW and 800 moths released at four sites in Victoria (200/site). In February 2018, 200 moths were collected for release at two sites in Victoria. Refer to Attachments 2-4 and 7 for release site details for Victoria (also **Error! Reference source not found.**1), South Australia and New South Wales.

Figure 11. New gorse soft shoot moth releases conducted in Victoria (clockwise from top left); Ballarat Council staff releasing larvae at a reserve in central Victoria; South West Goulburn Landcare facilitator Sonia Sharkey and University of Melbourne Science and Technology intern Nina Guo releasing adult moths along a creek in Wandong; Greg Lefoe (Agriculture Victoria) trialling a tent release to temporarily contain adults.

4.2.1 Field days and workshops

Over 200 producers, land managers, scientists and students participated in more than 19 field days, workshops and related events in Tasmania and Victoria (Table 2). 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. Field collections of gorse soft shoot moth in Tasmania mostly involved project partners from State agencies and NRM's who transferred agents to their respective States. One of the agent collection field days in Tasmania, held from the 14-15 Feb 2017, was showcased in two videos published on You Tube by Agriculture Victoria (https://youtu.be/IHP4JzUYfAw) and Murray Darling Basin NRM (https://youtu.be/pdxTVg_a-GY). Subsequent release and monitoring field days often followed the 'train-the-trainer' or 'local champion' model, where it was important to engage with locals who passed on knowledge through their local networks.

The three weed biological control workshops at the Seymour Alternative Farming Expo were an exception to this model, but nevertheless effectively targeted 60-70 producers who were interested in biological control of weeds. Many of the Expo participants were from areas where gorse is abundant, and the workshop focused on biological control of gorse, as well as co-occurring weeds such as English broom and Cape broom. A laptop and projector were available in the marquee, which allowed the features of the Biocontrol Hub and Atlas of Living Australia to be displayed. The response from participants strongly supported the Biocontrol Hub approach, as participants commented that they didn't previously know how to access information about biocontrol of gorse, or how to implement biocontrol on their properties.

Table 2. Field days, workshops and related events conducted in Tasmania and Victoria, 2015-2018.

Date	Event type	Description	Purpose	Participants
Tasmania				
7-16/12/2015	Field day	Richard Holloway provided detailed information on site management and the agent's biology to the following landholders/land managers at the time releases were carried out or during surveys.	Agent release, Training and knowledge transfer	8 Producers Henry Edgell (Bothwell); Andrew McShane Melton Mowbray; Richard Archer (Carrick); Ben Grubb (Breadalbane); Ben Flear and John Cusick (Apslawn); Brendon Ayres (Buckland); Alan Irish (Penguin).
9/02/2016	Field day	Richard Holloway and John Ireson conducted a field day at Melton Mowbray on the biology of gorse soft shoot moth and methods for its collection, consignment and release. Moths were collected from the site and air-freighted to South Australia and NSW for field release.	Agent collection Training and knowledge transfer	2 Public land managers Scott Hutchens and Sandy Cummings (South Australian Murray–Darling Basin NRM Board) 1 Scientist/State Government Officer Paul Sullivan (Industry & Investment NSW, Coordinator of Biological Control).
7-13/12/2016	Field day	Richard Holloway provided detailed information on site management and the agent's biology at the time releases were carried out or during surveys.	Agent release Monitoring Training and knowledge transfer	7 landholders/land managers Colin Jones (Campbell Town); Andrew McShane Melton Mowbray; Richard Archer (Carrick); Ben Grubb (Breadalbane); Ben Flear and John Cusick (Apslawn); Henry Edgell (Bothwell).
14-15/02/2017	Field day	Richard Holloway and John Ireson conducted a field day at Melton Mowbray on the biology of gorse soft shoot moth and methods for its collection, consignment and release. Moths were collected from the site and air-freighted to South Australia, NSW and Victoria for field release. Moths were also collected to enable two releases in Tasmania.	Agent collection & shipment Agent release Training and knowledge transfer	8 scientists and land managers Scott Hutchens and Sandy Cummings (South Australian Murray –Darling Basin NRM Board), Rob Murphy and Jim Donnelly (South Australian Adelaide and Mount Lofty Ranges NRM Board), Paul Sullivan (Industry & Investment NSW coordinator of Biological Control), Dr Andrew

				McConnachie (Weed Research Unit, NSW Department of Primary Industries Biosecurity, Orange), together with Greg Lefoe and Raelene Kwong from Vic DEDJTR.
30/11/2017-7/12/2017; 13/2/2018)	Field days (several)	Richard Holloway and John Ireson conducted a field day at Melton Mowbray on the biology of gorse soft shoot moth and methods for its collection, consignment and release. Richard Holloway provided detailed information on site management and the agent's biology at the time releases were carried out or during surveys	Agent collection & shipment Agent release Monitoring Training and knowledge transfer	11 Landcare members and landholders/land managers Sandy Leighton (Weeds Officer, Southern Midlands Council), who also took part in a moth collection/redistribution with Greg Lefoe (Vic DEDJTR) at Melton Mowbray on 13 February), Anna Povey (Conservation Programmes Officer, Launceston) , Lindsay Dobson (Buckland), Colin Jones (Campbell Town); Andrew McShane Melton Mowbray; Richard Archer (Carrick); Ben Grubb (Breadalbane); Ben Flear and John Cusick (Apslawn); Henry Edgell (Bothwell).
Victoria				
9/11/2015	Field day	Greg Lefoe provided information on site management and the agent's biology during site assessments at The Oaks.	Site assessment Training and knowledge transfer	4 land managers (DELWP (Vic)and VicForest staff)
24/11/2015	Field day	Greg Lefoe provided information on site management and the agent's biology at a field day at The Oaks.	Site assessment Training and knowledge transfer	11 land management staff from DELWP, Melbourne Water, Parks Victoria, West Gippsland CMA, Lake Mountain Resort, Yarra Ranges Shire and Baw Baw Shire.
7-17/12/2015	Field day	Greg Lefoe provided detailed information on site management and the agent's biology at the time releases were carried out or during pre-release site inspections.	Site assessment Agent release, Training and knowledge transfer	3 producers Greg Miles (Metcalfe), Jon Sayer (Woodend), and Pip Elston (Sidonia).
7 December 2016	Field day	Greg Lefoe conducted 4 releases with council officers responsible for maintaining multiple release sites, and who will lead local redistribution efforts when the agent is established. Content covered included release method,	Agent release, Training and knowledge transfer	2 Ballarat City Council vegetation management officers

		life-cycle information, and site management.		
20 December 2016	Field day	Greg Lefoe delivered training on monitoring and recording methods, and establishment of GSSM was subsequently detected by one of the students at the Elston property. Both Pip Elston and the other Landcare representative plan to extend their knowledge to other Landcare members in their area and Pip has recently (as of April 2018) assisted MLA in developing a case study.	Monitoring Training and knowledge transfer	4 producers and students Pip Elston (property owner, site manager & Baynton Sidonia Landcare group representative), one other local Baynton Sidonia Landcare representative, and two students Ha My Pham and Nick May (University of Melbourne and Deakin University respectively).
17 Feb 2017	Field day	Greg Lefoe conducted releases of GSSM at four sites in the Kilmore area. Content covered included site selection, release method, life-cycle information, and site management. Sonia Sharkey manages several gorse biocontrol release sites in the Kilmore area, and provides updates on site management and biocontrol to her property owners and Landcare groups.	Agent release, Training and knowledge transfer	Sonia Sharkey (Landcare Facilitator) and two University of Melbourne students (Nina Guo and William Concepcion).
16 Feb 2017	Workshop	Greg Lefoe facilitated an expert elicitation workshop in Hobart. The workshop used a modified Delphi method to identify factors that could favour or prevent the establishment of GSSM on mainland Australian. Several factors favouring GSSM, were recorded and will be used to construct a Bayesian Belief Network (model) as part of an adaptive management approach to biocontrol redistribution.	Knowledge transfer	2 Scientists Dr John Ireson (TasWeed Biocontrol) and Dr Raelene Kwong (DEDJTR)
17 Feb 2017	Workshop	Seymour Alternative Farming Expo Greg Lefoe delivered a workshop on gorse and broom biocontrol. The presentation included displays of GSSM.	Knowledge transfer	20-30 producers

June 2017	Seminar	Weed Society of Victoria AGM and Seminar Greg Lefoe, DEDJTR, AgriBio, La Trobe University, Vic, showcased the Biocontrol Hub using GSSM as a case study.	Knowledge transfer	8 weed managers
18 Sept 2017	Conference	Australian Entomological Society Conference, Terrigal, NSW Greg Lefoe showcased the Biocontrol Hub using gorse as a case study.	Knowledge transfer	approx. 60 participants (mostly scientists, biosecurity & technical staff, policy staff, students)
15/02/2018	Field day	Greg Lefoe conducted a field day at Elaine where two releases of gorse soft shoot moth adults (approx. 100 adults per release) were conducted. The release was covered by WIN TV News, who interviewed Greg, as well as a local producer and a member of the Victorian Gorse Task Force.	Agent release, Training and knowledge transfer Media and communications	4 producers/community volunteers (Victorian Gorse Task Force) 1 scientist (University of Melbourne) 2 WIN TV News reporters
16 & 17/2/2018	Workshops (x2)	Seymour Alternative Farming Expo Greg Lefoe delivered two workshops on biological control. Gorse soft shoot moth was selected as the focus of the presentations as it is a major weed problem in Seymour and surrounding districts.	Knowledge transfer	40 producers
Planned 26-31 August, 2018	Conference	International Symposium on Biological Control of Weeds, Switzerland Greg Lefoe submitted a poster abstract on maximising establishment of the gorse soft shoot moth.	Knowledge transfer	
			Total number of events: **Est. number of participants:**	**19+** **211**

4.3 Collection and identification of fungi damaging gorse

Symptoms of severe leaf blight and die back (Attachment 1) were particularly noticeable and widespread at Bothwell, Melton Mowbray and Lymington where high densities of gorse soft shoot moth larvae had caused extensive damage to gorse foliage together with the gorse spider mite and gorse seed weevil. At Bothwell, Melton Mowbray and Lymington the fungus identified was *Paraconiothyrium* sp. This species caused severe damage by penetrating the plant's vascular system. At Carrick, severe leaf blight was caused by the fungus *Alternaria brassicae*.

5 Discussion

Results obtained by Ireson and Holloway (2014) suggested that the release of adults could possibly increase the success of establishment and may therefore be preferable to the release of larvae. However, collecting adults is more resource intensive than collecting larvae. From monitoring conducted in this project, there is no evidence of a difference in establishment rate between adults and larvae. Collecting and releasing larvae is therefore more efficient in terms of time and resources and is now the preferred method where larvae are abundant and readily available.

The latest data also show that the gorse soft shoot moth is unlikely to establish in inland regions of northwest Tasmania where the mean annual rainfall is ca. 1500 mm, despite multiple releases in this location. The apparent effect of the rainfall is unclear but, as the agent spends about nine months (including winter) in the adult stage sheltering within the gorse (Ireson et al. 2013), heavy rainfall or associated high humidity could have a negative impact on adult survival. The results also suggest that shading at release sites could reduce establishment success, but the reason is again unclear, and more data is required to confirm this. Most of the Tasmanian gorse infestations occur in the low rainfall pasture ecotypes within the 800 mm annual isohyet (Ireson et al. 2007) and the results indicate that the gorse soft shoot moth should become widespread in these locations and perform best in open country not subjected to shading. Within these areas, it is evident that the condition of the gorse at the time of release is an important consideration. For instance, excessively dry conditions have resulted in significant stress on the gorse at some sites in Tasmania and mainland States, which affected the production of new spring growth. A lack of new growth would not be conducive to the survival and development of larvae (Ireson et al. 2013). Dry conditions affect gorse architecture and compact, lush gorse provides better shelter for diapausing moths as opposed to drought stressed bushes which have a more open canopy and poor growth.

Earlier preliminary survey results presented by Ireson and Holloway (2014) indicated that establishment is achievable through either the open release of 500 larvae/site or between 100-200 adults/site, and these remain the recommended release thresholds. Increasing the success of establishment at individual sites may be achievable by increasing the number of larvae or adults released per site. It would be easy to increase the number of larvae released per site when they are present in high densities at the nursery site, as the larvae are so easy to collect. However, as the collection of adults is more labour intensive, an open release of only 100 to 200 adults per site is considered optimal as it has resulted in field establishment. In New Zealand, open releases of 100 adults or larvae ranging from 500-1000 per site have also resulted in field establishment (Gourlay pers. com.). Based on observations discussed in preceding paragraphs, it is likely that climatic and other variables conditions at the site and the time of release will have an overriding impact on the success of the releases.

Gorse soft shoot moth is univoltine (Ireson et al. 2013) and at least two to three field generations (i.e. two to three years) will be required to determine whether permanent field establishment has

occurred from these releases. This could vary between sites depending on the conditions prevailing during the years after release. Densities high enough to harvest for redistribution occurred at Jericho (Tas), five years after release and at Melton Mowbray (Tas) only four years after release whereas in New Zealand, gorse soft shoot moth field populations were difficult to locate until the presence of high density populations were located 15 years after release (Hill et al. 2008).

A number of factors can affect the field establishment and population density of a biological control agent. These can vary from site to site and include the prevailing weather conditions at the time of release, climate, the presence of parasites and predators, host plant quality and release strategy which also involves choosing a suitable number of the agents for release (Day et al. 2004; Spafford et al. 2008). To aid future site selection and release strategies, development of a Bayesian Belief Network (BBN) commenced to capture monitoring results and expert opinion of the factors that favour gorse soft shoot moth establishment. Although additional to project achievement criteria, development of the BBN would provide valuable insight into what makes a successful release. The aim is to address a key shortcoming in biological control implementation, whereby decisions are often made when 1) there is insufficient data or knowledge of a new agent to make well informed site selection decisions, and 2) it takes many years to acquire useful data and update knowledge. The BBN will provide a process model for predicting outcomes of actions based on current knowledge (usually qualitative), with a view to updating the model with data as monitoring data becomes available. The model has been developed through several iterations, with the next step (step 5, below) being a formal expert elicitation exercise to parameterise variables (outside the scope of this project). The BBN will facilitate adaptive management approaches and aligns closely with sub-project 'WBC.0090 Biocontrol portal and app' (which provides a repository for the long-term monitoring data that is essential for updating the BBN). Model development will continue in a related PhD project, applying the following process, and is expected to be submitted for publication in the second half of 2018:

1. define the objective of the model and describe the intended users; (completed),
2. develop a conceptual model of how the system works, (completed),
3. translate the conceptual model to an influence diagram, showing the causal links between variables in the system, (completed),
4. describe the variables and their possible states, (completed),
5. parameterise the model using qualitative and/or quantitative data, (in progress),
6. evaluate the sensitivity and accuracy of the model, and
7. test model predictions using typical scenarios.

European investigations have shown that there are no additional invertebrate species that are considered suitable as biological control agents for gorse (Sheppard and Thomann 2005) and there are no suitable exotic fungal pathogens available (Jourdan 2009). A submission to obtain permission for the release of a fifth agent, the gorse pod moth, *Cydia succedana* (Denis & Schiffermüller), was rejected by quarantine authorities due to concerns about its host specificity (Ireson unpublished data).

The individual impacts of *A. umbellana, E. ulicis, T. lintearius* and *S. staphylinus*, which are the full complement of agents currently available for the biological control of gorse in Australia, are not known to be lethal to mature plants. However, accelerating the dispersal of *A. umbellana* across south-eastern Australia should be a priority. The combined impact of this guild of agents, whether it be sub-lethal effects on plant health, a reduction in seed output or increasing susceptibility to fungal attack, or their possible use as part of an integrated management programme can then be determined (Hill et al. 2008; Ireson et al. 2013).

Results from surveys suggest that feeding by the biological control agents, particularly the gorse soft shoot moth, can increase susceptibility to attack by fungi and this may become a significant factor in

suppressing the spread of gorse in the future. One of the fungi identified in the Tasmanian surveys (*Altenaria brassicae*) had previously been identified as causing severe leaf blight to gorse at Carrick, Melton Mowbray and Tolman's Hill, Tasmania, in May 2013 (Ireson unpublished data). Although gorse can recover from extensive leaf blight caused by this fungus (Ireson unpublished data), the other fungus identified, *Paraconiothyrium* sp., appears to be more damaging as it can infiltrate the plant's vascular system. Gorse bushes may therefore find greater difficulty recovering from attack, particularly if the gorse is subjected to further stresses such as additional attack from the biological control agents or continuous drought. The significance of these fungal attacks on gorse and the factors associated with it should be further investigated. It is recommended that further surveys be conducted to find the extent of association between fungal attack and feeding by biological control agents. Investigations should initially focus on determining the fungi involved, their level of pathogenicity and whether the biological control agents are themselves also capable of transporting the pathogens and initiating attack. The significance of their effect on gorse should also be determined.

5.1 Reference List

See Attachment 1

5.2 Lessons learnt and Key messages

What worked well	Monitoring previous Tasmanian release sites at the commencement of the project updated knowledge of the distribution and abundance of gorse soft shoot moth. This was valuable for subsequent project planning, as sites with large gorse soft shoot moth populations were targeted for collections and field days. In addition, continued monitoring of gorse soft shoot moth sites in Tasmania and other States provided valuable data on the site conditions that favoured establishment. These results informed the selection of new release sites. Collaboration between on-ground and interstate partners strengthened throughout the project, and new partners were identified. Joint meetings of the RR&D4P Round 1 and Round 2 project leaders provided a welcome forum for sharing resources and discussing and resolving issues confronting biological control in Australia. Collaborative redistribution efforts expanded during the project, with NSW DPI and an additional South Australian NRM participating in gorse soft shoot moth redistribution. Developing linkages with the University of Melbourne and Monash University facilitated access to modelling expertise that would not otherwise be available to the project. For example, a paper on the application of Bayesian networks to inform site selection is planned. Such models could be used as part of an adaptive management approach to biological control agent introduction.
What didn't go so well	The widespread adoption of social media tools provides opportunities

	that are currently underutilised. The opportunity to participate in redistribution field days (where participants can not only learn about biocontrol but collect and redistribute agents on the same day) often comes at short notice, or is rescheduled at the last minute, because agent availability and weather are uncertain or change. The success of individual events is also difficult to predict. In these cases, streamlined communications protocols (involving the use of social media, for example), could provide timely updates. Timely media communications could increase the impact of biocontrol agent events, such as field days and workshops, by 1) encouraging producers, land managers and community volunteers to participate in upcoming events, and 2) stimulating broader interest in biocontrol. However, existing media approval processes may not allow individual researchers to quickly update news on social media. Live updates are currently not exploited for the same reasons. The February 2017 field day in Tasmania is an example of an event that was very successful (because very large numbers of agents were collected for redistribution to mainland states), and where the excitement and benefits of the event could have been communicated via live Twitter feeds or Facebook updates.
What would you do differently	There was discussion at RR&D4P project meetings of streamlining media approvals via MLA and DAWR. Similar discussions were initiated with DEDJTR to expedite approval of communications at the sub-project level. One option is to identify, and pre-approve (or expedite), routine, low risk communications such as updates about biocontrol field days. Another option is to utilise enhanced Blog features on the Biocontrol Hub to update biocontrol Communities of Interest. Monitoring is necessarily constrained by the difficulty in detecting gorse soft shoot moth when populations are low (especially in the first 1-3 years post-release, but sometimes longer). Producer and land manager expectations of agent detection should therefore be carefully managed. 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 that an agent is absent, given that it was not detected. Land managers and producers would therefore be better informed when making decisions whether to persist with, or abandon, release sites.

5.3 Recommendations (priorities for further work)

Areas of work that are a priority for gorse soft shoot moth in Australia include:

1. Investigate the potential contribution of naturally-occurring plant pathogens to gorse biological control, apparent associations with introduced insect agents, and long-term impacts of biological agents on gorse populations (see Section 8.2).
2. Encourage ongoing monitoring of new sites through producer and land manager networks, especially use of the Biocontrol Hub app to capture and share monitoring results.
3. Promote the continued redistribution of gorse soft shoot moth across south-eastern Australia once the agent becomes abundant at mainland sites. This could be achieved efficiently by supporting on-ground networks, such as Landcare, and exploiting the monitoring and engagement potential of the Australian Biocontrol Hub web-site and app.

5.4 Sub-Project level achievements

The project level achievements are outlined below and in Attachment 5.

5.4.1 Activity: Gorse - Mass-rearing and redistribution of the gorse soft shoot moth (GSSM) will be accelerated to target heavily gorse-infested farmland.

Output	KPI description	Progress achieved against KPI	Outputs
5a	KPI 1.9 – Advise the Department of GSSM monitoring protocols	☒ **Achieved** ☐ **Partially achieved** ☐ **Not achieved**	Protocols were prepared to standardise follow-up monitoring of release sites. The protocols were developed in Tasmania at sites where GSSM is present. The protocol balances detection rate, with time, resource and training constraints. The protocol recommends monitoring in December to coincide with the period when late-instar larvae are most likely to be abundant in the field. Following the protocol, each site was assessed for the presence of larvae by conducting a 10-minute (minimum) search of the point of release. If larvae were located, dispersal around the central release point was traced by checking gorse bushes every 25-50 m until no larvae could be detected. The monitoring protocol has been published on the Bioocontrol Hub's gorse soft shoot moth survey description and the draft update to the Gorse Weed Management Guide.
5b	KPI 1.9 _ Progress with GSSM monitoring commenced at 4 sites in Vic, 3 sites in SA and 6 sites in Tas	☒ **Achieved** ☐ **Partially achieved** ☐ **Not achieved**	**GSSM monitoring** Monitoring for agent establishment, spread and abundance was conducted at 8 existing release sites in Victoria, and 75 existing release sites in Tasmania (67 more sites than the target of 8). Sites with the highest population densities that were suitable for collections were located in the Tasmanian midlands at Jericho and Melton Mowbray. At the 31 Tasmanian sites where the agent was recovered, populations have permanently established and are spreading at 19 (61%) of these, and were recovered around the release point at another 12 (39%) sites ("permanently established" indicates that the agent has survived at the site for at least 1 year and is spreading from the release point). Gorse soft shoot moth has now spread over at least 450 sq. km in an area between Kempton and Oatlands, Tasmania. Sites suitable for collections were added to the ALA. 14 new release sites were monitored in Victoria and 14 new release sites were monitored in Tasmania. Despite a delay at the beginning of the project, there were 16 monitoring events conducted at existing sites in South Australia.
	KPI 3.8 – Advise the Department of progress of GSSM monitoring and results recorded in ALA biocontrol portal.	☒ **Achieved** ☐ **Partially achieved** ☐ **Not achieved**	
	KPI 5.6 – Report to the		

	Department on results of GSSM monitoring at 12 sites in Vic, 3 sites in SA and 8 sites in Tas and that GSSM has been recorded on ALA biocontrol portal for all monitored sites where establishment has occurred.	☒ **Achieved** ☐ **Partially achieved** ☐ **Not achieved**	
	KPI 4.8 – Advise the Department of GSSM releases at 6 sites in Victoria and 6 sites in Tasmania	☒ **Achieved** ☐ **Partially achieved** ☐ **Not achieved**	**GSSM releases** Gorse soft shoot moth was introduced at 22 new sites in Victoria and 16 new sites in South Australia. Releases in South Australia were conducted as planned by Adelaide Mount Lofty Ranges (AMLR) NRM. South Australia Murray Darling Basin NRM and AMLR NRM conducted additional gorse soft shoot moth releases that were partly funded by other sources, but made possible through engagement with this project. 24 new releases were conducted in Tasmania to address distribution gaps in that State.
	KPI 6.8– Report to Department on the release of GSSM at 8 sites in Victoria, 2 sites in SA and 6 sites in Tasmania	☒ **Achieved** ☐ **Partially achieved** ☐ **Not achieved**	
5c	KPI 2.7 – Advise the Department of outcomes of field days	☒ **Achieved** ☐ **Partially achieved** ☐ **Not achieved**	Over 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. Field collections of gorse soft shoot moth in Tasmania mostly involved project partners from State agencies and NRM's who transferred agents to their respective States. Release and monitoring field days often followed the 'train-the-trainer' or 'local champion' model, where it was important to engage with locals who passed on knowledge through their local networks. The three weed biological control workshops at the Seymour Alternative Farming Expo were an exception to this model, but nevertheless effectively targeted 60-70 producers who were interested in biological control of weeds.
	KPI 4.9 – Report on field days delivered at 2 sites in Victoria and 2 sites in Tasmania provided to the	☒ **Achieved** ☐ **Partially achieved** ☐ **Not achieved**	

	Department		
	KPI 6.8– Field days delivered at 2 sites in Victoria and 2 sites in Tasmania.	☒ **Achieved** ☐ **Partially achieved** ☐ **Not achieved**	

5.4.2 Project objectives summary

By 01 September 2018:

1) Collect gorse soft shoot moth (GSSM) from sites in Tasmania where the agent is established.

   Achieved. More than 25,000 gorse soft shoot moths were collected from Tasmanian sites where it is abundant.

2) Introduce GSSM at a minimum of 20 new sites across gorse-infested regions of Victoria and a minimum of 2 new sites in South Australia.

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

3) Address gaps in agent distribution by introducing GSSM at a minimum of 18 new sites in Tasmania.

   Exceeded. 24 new releases were conducted in Tasmania to address distribution gaps in that State.

4) Monitor 8 existing release sites in Victoria and 8 existing release sites in Tasmania (at least once in the first two years of the project), to determine agent establishment, spread and abundance. Assess suitability of each site for agent collections, and where applicable, collect data on agent impact.

   Exceeded. Monitoring for agent establishment, spread and abundance was conducted at 8 existing release sites in Victoria, and 75 existing release sites in Tasmania (67 more sites than the target of 8). Sites with the highest population densities that were suitable for collections were located in the Tasmanian midlands at Jericho and Melton Mowbray. At the 31 Tasmanian sites where the agent was recovered, populations have permanently established and are spreading at 19 (61%) of these, and were recovered around the release point at another 12 (39%) sites ("permanently established" indicates that the agent has survived at the site for at least 1 year and is spreading from the release point). Gorse soft shoot moth has now spread over at least 450 sq. km in an area between Kempton and Oatlands, Tasmania.

5) Monitor (at least once in the life of the project) 12 new release sites in Victoria and 12 new release sites in Tasmania, to confirm establishment of the agent.

   Exceeded. 14 new release sites were monitored in Victoria and 14 new release sites were monitored in Tasmania.

6) Monitor 9 existing sites in South Australia (three sites each year of the project) to determine agent establishment, spread and abundance. Assess suitability of each site for agent collections, and where applicable, collect data on agent impact.

   Exceeded. Despite a delay at the beginning of the project, there were 16 monitoring events conducted at existing sites in South Australia.

7) Capture and analyse establishment data and local knowledge to improve biocontrol success.

   Achieved. Establishment data, especially from Tasmanian sites, informed the selection of new release sites based on rainfall, shading and gorse condition. Releasing 500 larvae was found to be as effective as releasing 100 adults, but collecting larvae required fewer resources and less training.

8) Develop best practice recommendations to integrate biocontrol into production systems.

   Achieved. Content for an updated Gorse Weed Management Guide was drafted (Attachment 11). The existing Gorse Weed Management Guide was published in 2003, before the introduction of gorse soft shoot moth to Australia. The 2018 revision adds information on gorse soft shoot moth and integrated management, including 1) gorse soft shoot moth collection, release and monitoring advice developed in this project, 2) information on the Biocontrol Hub, and 3) updated links and contacts.

9) Deliver 6 field days/workshops in Victoria and 6 field days/workshops in Tasmania.

   Exceeded. More than 19 field days and workshops delivered in Victoria and Tasmania.

10) 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.

    Achieved. Content for an updated Gorse Weed Management Guide was drafted (Attachment 11). The existing Gorse Weed Management Guide was published in 2003, before the introduction of gorse soft shoot moth to Australia. The 2018 revision adds information on gorse soft shoot moth and integrated management, including 1) gorse soft shoot moth collection, release and monitoring advice developed in this project, 2) information on the Biocontrol Hub, and 3) updated links and contacts. In addition to requirements, significant progress was made on the development of a Bayesian Belief Network (BBN) to capture monitoring results and expert opinion of the factors that favour gorse soft shoot moth establishment. The BBN will be submitted for publication in the second half of 2018, and will provide a process model for predicting outcomes of actions based on current knowledge (usually qualitative), with a view to updating the model with data as monitoring data becomes available.

5.5 Contribution to project expectations

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

More than 25,000 gorse soft shoot moths released in four States.

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

Gorse occurs across 23 million hectares of Australia's land mass and infests up to 1 million hectares within that area. Gorse soft shoot moth has now spread over at least 450 sq. km. in an area between Kempton and Oatlands, Tasmania. New releases have been conducted in containment zones across much of the infested range in south eastern Australia.

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

Gorse soft shoot moth is now abundant and damaging gorse in Tasmania, and new releases have been conducted across south eastern Australia. Results from gorse surveys suggest that feeding by the biological control agents, particularly the gorse soft shoot moth, can increase susceptibility to attack by fungi and this may become a significant factor in suppressing the spread of gorse in the future

(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; and

More than 19 field days and workshops delivered and Gorse Weed Management Guide updated.

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

Collaboration across four States (Tasmania, Victoria, South Australia and New South Wales) to collect and release the gorse soft shoot moth.

6 Collaboration

See Attachment 6 "Gorse project Partner in-kind contribution 2015-18.xls" and the following attachments listed below.

Collaborator	Attachment
South West Goulburn Landcare	Attachment 6.1 16-17 SWG Letter of in-kind support signed.docx.pdf
South West Goulburn Landcare	Attachment 6.2 17-18 SWG Landcare confirmation.pdf
Adelaide and Mount Lofty Ranges NRM	Attachment 6.3 16-17 AMLR in-kind for MLA gorse biocontrol project.pdf
Adelaide and Mount Lofty Ranges NRM	Attachment 6.4 17-18 AMLR in-kind letter April 2018.pdf
TasWeed Biocontrol	Attachment 6.5 15-16 TasWeed Biocontrol statement of in-kind.pdf
TasWeed Biocontrol	Attachment 6.6 16-17 TasWeed Biocontrol statement of in-kind.pdf
Gorse Task Force	Attachment 6.7 16-17 Gorse Task Force statement of in-kind.pdf

Connecting Country	Attachment 6.8 15-16 Connecting Country statement of in-kind.pdf

7 Extension and adoption activities

Field days and workshops (**Error! Reference source not found.**2) were the main extension and adoption activities delivered in this project, and are reported in Table 2.

Figure 12 Extension activities, including field days and hands-on training, associated with the collection and release of agents. Clockwise from top left: field trip with public land managers to assess and select sites for upcoming biocontrol releases; learning about gorse soft shoot moth at a collection field day in Tasmania; conducting a "tent" release with a property owner in Victoria.

Gorse project content written for the ALA Biocontrol Hub

Content was written for the Biocontrol of gorse web-site on the ALA Biocontrol Hub, including information on the status of the biocontrol program, agent descriptions and photos, and links to on-line resources and YouTube videos (Attachment 8). An image from the hub is shown in Figure 13.

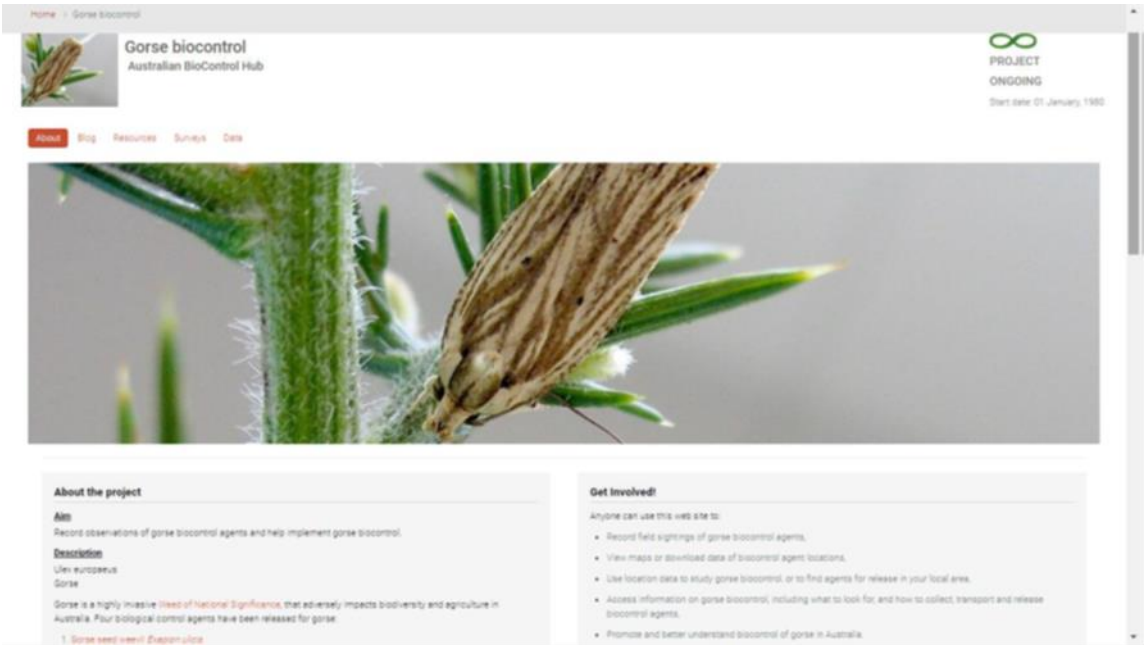


Figure 13 Screen shot from gorse ALA biocontrol hub.

Gorse Weed Management Guide

Knowledge obtained through monitoring and producer feedback was incorporated into a draft update of the WoNS Gorse Weed Management Guide (see Section 4.1 and Attachment 11).

MLA-led communications tasks

In late-April 2018 Greg Lefoe assisted the following MLA-led communications tasks:

1. Developing a producer case study (Pip Elston of Baynton, Vic) including an interview with a MLA journalist.

2. Disseminating an online evaluation to gorse stakeholders.

3. Interviewed by another MLA journalist on 2 May, 2018

8 Financial Statement

A financial acquittal for the project is included showing in-kind and cash contributions. All funds were expended.

8.1 Project partners

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

Dept. Environment. Land, Water and Planning (Vic) & Central Highlands Eden Project partner agencies.

University of Melbourne

(See Attachment 6 "Gorse project Partner in-kind contribution 2015-18.xls")

8.2 Additional Funds

If additional funds (<$40k) were made available to your sub-project, what would you be able to deliver to value add and ensure greater impacts of the projects.

Results from surveys suggest that feeding by gorse agents, particularly the gorse soft shoot moth, can increase susceptibility to attack by fungi and this may become a significant factor in suppressing the spread of gorse in the future. The significance of these fungal attacks on gorse and the factors associated with it should be further investigated. It is recommended that further surveys be conducted to find the extent of association between fungal attack and feeding by biological control agents. Investigations should initially focus on determining the fungi involved, their level of pathogenicity and whether the biological control agents are themselves also capable of transporting the pathogens and initiating attack. The significance of their effect on gorse should also be determined. With the suggested allocation of funds(<$40K) this may be suitable as a post-graduate project (MSc or PhD) conducted over 2-3 years.

9 Appendices/Attachments

- Attachment 1-Tasmania technical report with release sites and monitoring results.pdf
- Attachment 2-Victoria release and monitoring data 2015-18.docx
- Attachment 3-South Australian Release Sites.xlsx
- Attachment 4-NSW release sites.xlsx
- Attachment 5-Log frame WBC.0050 gorse.docx
- Attachment 6-Gorse project partner in-kind contributions 2015-18.xlsx
- Attachment 6.1-16-17 SWG Letter of in-kind support signed.docx.pdf
- Attachment 6.2-17-18 SWG Landcare confirmation.pdf
- Attachment 6.3-16-17 AMLR in-kind for MLA gorse biocontrol project.pdf
- Attachment 6.4-17-18 AMLR in-kind letter April 2018.pdf
- Attachment 6.5-15-16 TasWeed Biocontrol statement of in-kind.pdf
- Attachment 6.6-16-17 TasWeed Biocontrol statement of in-kind.pdf
- Attachment 6.7-16-17 Gorse Task Force statement of in-kind.pdf

- Attachment 6.8-15-16 Connecting Country statement of in-kind.pdf
- Attachment 7-Gorse soft shoot moth monitoring and release maps.pdf
- Attachment 8-Biocontrol Hub gorse content.pdf
- Attachment 9-Moths set flight in the fight against problem gorse Meat & Livestock Australia.pdf
- Attachment 10-2017-02_22_Grampians News.pdf
- Attachment 11-Draft Gorse Weed Management Guide 2018.docx

9.1 Project, media and communications material and intellectual property

YouTube

One of the agent collection field days in Tasmania, held from the 14-15 Feb 2017, was showcased in two videos published on You Tube by Agriculture Victoria (https://youtu.be/IHP4JzUYfAw) and South Australia Murray Darling Basin NRM (https://youtu.be/pdxTVg_a-GY).

Media

A MLA media release "Moths set flight in the fight against problem gorse" was published on the MLA web-site (refer to Attachment 9). The media release was prepared to coincide with a release of gorse soft shoot moth in Elaine, Victoria. The event was covered by WIN TV News (Ballarat) and was featured on the WIN TV Facebook page, which has around 20,000 followers across regional Victoria. The sub-project Leader Greg Lefoe, a local producer, and a member of the Victorian Gorse Task Force were interviewed (**Error! Reference source not found.**). Two other Victorian Gorse Task Force committee members were present, along with Dr Cindy Hauser of Melbourne University. Greg Lefoe also participated in two radio interviews; Ace Radio (regional Victoria) (https://soundcloud.com/user-895414954/release-the-moth-to-eat-the-gorse?utm_source=soundcloud&utm_campaign=share&utm_medium=facebook) and ABC Radio Launceston. Anecdotally the Elaine news story was picked up by smaller Landcare and farmer newsletters (See Attachment 10 for an example from the Grampians article).

Figure 14. Gorse sub-project leader Greg Lefoe (DEDJTR, Agriculture Victoria) being interviewed by WIN TV News at a gorse soft shoot moth release and field day in Elaine, Vic.

9.2 Equipment and assets

n/a

9.3 Staffing levels

–	**Full time equivalent staff (FTE) and type of position**
–	**Gorse** • 0.35 FTE: Greg Lefoe (DEDJTR Vic) Project Leader, Monitoring and redistribution, Coordination. • 0.1 FTE: Casual labour (Richard Holloway) - Monitoring of Tasmanian sites; collection & shipping of agents to mainland states.