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Manaaki Whenua
Landcare Research

Weed Biocontrol

WHAT'S NEW?

Contents

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COVER IMAGE:
Gorse seed weevil on gorse

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Focusing on the Insect Microbiome

The microbiome of insects contains microscopic organisms such as bacteria that allow insects to change their physiology to cope with different environments – a handy trait called phenotypic plasticity. The microbes that make up the microbiome of an individual insect are diverse and spread-out, for example living in the insect's gut, its reproductive organs, and in specialised tissues (the bacteriome). Advances in molecular ecology are showing how important the microbiome is for insect fitness, allowing insects to expand into novel ecological niches and environments in ways that could have important implications for weed biocontrol.

Molecular biologist Claudia Lange is currently leading two areas of research related to insect microbiomes. The first involves investigating the effects of gut microbes on insect performance across native and introduced ranges. This research was prompted by the discovery in 2008 of a small population of St John's wort beetles that appeared to be persisting on a population of native *Hypericum* species (a mix of mainly *H. involutum* with some *H. rubicundulum*). St John's wort beetles (*Chrysolina hyperici* and *C. quadrigemina*) were released as biocontrol agents for this weed in New Zealand between the 1940s and 1960s.

St John's wort (*Hypericum perforatum*) is an invasive pasture weed in New Zealand and in many other countries beyond its native range of Europe and North Africa, and St John's wort beetles are highly effective biocontrol agents. Best-practice host-specificity testing at the time the beetles were released in many parts of the invaded range was focused on crop species and neglected to test closely related native hosts. Retrospective tests in 2008/09 have shown that the native plant species are indeed within the fundamental host range of the beetles, which can complete development on *H. involutum* in the laboratory just as well as they do on St John's wort. Yet populations of *H. involutum* in nature do not appear to be under attack, other than this one small population discovered in 2008. This led to the question of whether changes to the microbiome have enabled the beetles to persist on the native *H. involutum* at that one site, and what this could mean for the long-term safety and effectiveness of weed biocontrol agents.

Claudia and her team will use genetic profiling to identify microbial taxa that are specific to the insect and to the host plant, comparing European and New Zealand insect and plant specimens. The knowledge we gain from this project will be valuable for understanding the potential for host range shifts and associated biological risks posed by other herbivorous insects introduced into novel environments to control invasive weeds.

Another major goal of this project is to establish a productive collaboration with the Max Planck Institute for Chemical Ecology in Jena, Germany. The institute is one of 86 institutes of the Max Planck Society, Germany's most successful research organisation.

Claudia Lange

Claudia is working closely with the director of the Department of Insect Symbiosis, Professor Martin Kaltenpoth, whose research focuses on the molecular basis, ecological impact, and evolutionary history of symbiotic associations between insects and beneficial microbes. Claudia also aims to establish links with other organisations to co-develop research agendas relevant to biosecurity, biodiversity, biocontrol and conservation in the longer term.

In 2022 Claudia visited the Max Planck Institute for a 2-month research stay. This visit allowed her to collect samples of St John's wort beetles in their native range, and to analyse them in world-class laboratories with advice from her new insect symbiosis colleagues. The extended visit was an excellent opportunity to meet experts, attend seminars and learn new skills.

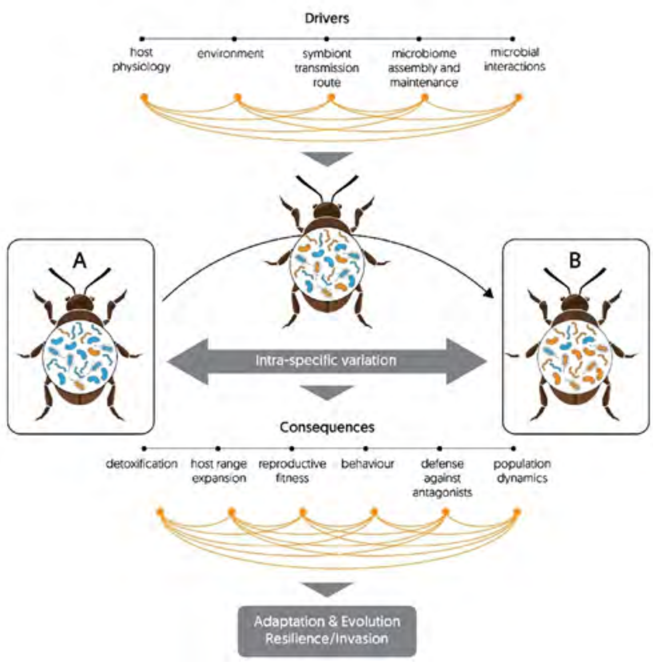
Back in New Zealand, Claudia is collecting beetles from St John's wort and native *Hypericum* species to compare their microbiomes among different host plants and with the microbiomes of beetles collected from St John's wort in Germany. There will be further research exchanges between Germany and New Zealand in the coming year, which may also involve research on other leaf beetles, such as New Zealand endemic beetles in the subfamily Chrysomelinae, and European pest species in New Zealand such as the mint leaf beetle (*Chrysolina herbacea*).

The second aspect of Claudia's research is looking at the impact of intraspecific variation in insect microbiomes on host phenotype and evolution. This is an 'Outside Thinking – Brilliant Writing' initiative, which aims to establish a new international collaboration and produce a synthesis paper about the development of a new research agenda. A group of six Manaaki Whenua – Landcare Research (MWLR) researchers from the Biocontrol & Molecular Ecology team were interested in increasing understanding of the impact of insect microbiomes on the hosts and the environment.

In 2021 the researchers facilitated a discussion session 'Implications of switching invertebrate microbiomes on interactions with plants' at the Symposium on Insect–Plant Interactions (Leiden, The Netherlands) to explore the interest of the international research community. Over 50 delegates attended the discussion, and the majority emphasised the need to investigate the functional impacts of changed microbiomes on species interactions. The international consensus was that integrated research approaches are needed as the next logical step to improve the management of invasive insects. Five of the delegates joined our team to work collaboratively on research ideas, publications and funding proposals. For a year Claudia and the team had regular meetings with international collaborators.

When Claudia was awarded the 'Outside Thinking – Brilliant Writing' funding in 2022 the group were already well prepared to start working on the synthesis paper. Most of the planning and writing were done by Zoom meetings, but some team members were also able to travel to Europe to meet in person. During Claudia's trip to Europe in 2022 she visited the French, German, Swiss and Dutch collaborators. One French collaborator was also able to travel to New Zealand to attend one of our two paper-writing workshops in person.

The review paper identifies a lack of understanding of how intraspecific variation in the assembly and function of insect-



Schematic diagram of insect microbiome effects

associated microbial communities can shape plasticity in insects. The paper highlights that most research focuses on the core microbiome associated with a species of interest and ignores intraspecific variation (variation between individuals of the same species). The authors argue that microbiome variation among insects can be an important driver of evolution, and provide examples of how such variation can influence the fitness and health of insects, insect invasions, their success and persistence in new environments, and their responses to global environmental change.

Their schematic diagram illustrates the complexity of interacting factors, where A and B are two stages of an individual insect or a population of the same species. The drivers (host physiology, environment, symbiont transmission route, microbiome assembly and maintenance, and microbial interactions) lead to a shift in the insect-associated microbial community, which has consequences for the host (for example, detoxification, host range expansion, reproductive fitness, behaviour, defence against antagonists, and population dynamics). This complex interplay of consequences has effects on insect adaptation and evolution, and influences insect population resilience or invasion.

This demonstrates how important it is for us to understand the insect microbiome and its role in the safety and effectiveness of weed biocontrol agents. For this reason it is currently a priority area of research for our Biocontrol & Molecular Ecology team at MWLR. Claudia's research group have submitted their synthesis paper as a foundation for this area of research which has just been accepted for publication.

These projects are funded by the Royal Society of New Zealand, and the Ministry of Business, Innovation and Employment's Strategic Science Investment Fund (SSIF).

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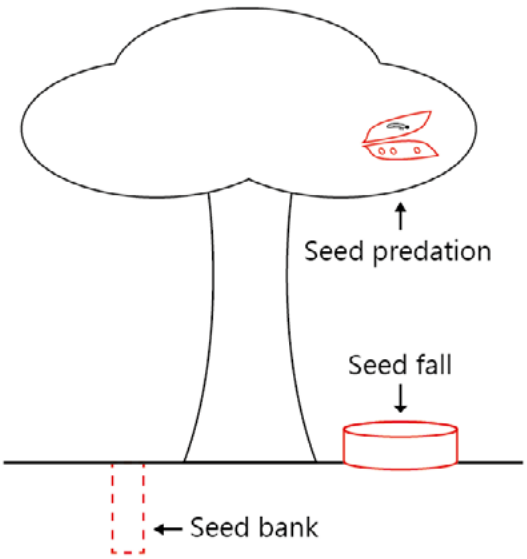
Are Gorse Seed Feeders Hungry Enough for Change?

Gorse (*Ulex europaeus*) was originally introduced to New Zealand early in the 19th century as a hedging plant. At the time, having a prickly plant to keep the animals in and the neighbours out probably seemed like a good idea. But fast forward to today and it is one of the most complained about weeds in New Zealand. It is widespread throughout the country, and both expensive and time consuming to control, which explains why gorse has been a target for biocontrol since the 1930s.

Six biocontrol agents have been successfully established to control gorse, starting with the gorse seed weevil (*Exapion ulicis*), which was first released in 1931. At the time, a seed feeder was chosen to reduce the spread of the weed but avoid affecting gorse hedges. Later the gloves came off in the biological fight against gorse and new agents were introduced and established in the 1990s: the gorse pod moth (*Cydia succedana*), gorse soft shoot moth (*Agonopterix umbellana*), gorse spider mite (*Tetranychus lintearius*), and gorse thrips (*Sericothrips staphylinus*), and lastly the gorse colonial hard shoot moth (*Pempelia genistella*) in 1998.

Thirty years on from the bulk of these releases, and Paul Peterson and colleagues have started investigating the impact of these biocontrol agents on gorse populations. The focus of their recent work has been on gorse seed feeders (i.e. the gorse seed weevil and gorse pod moth). Gorse produces a prolific number of seeds that help it to persist across landscapes. Because of this trait, seed feeders have been seen as a key component of successful biocontrol and overall management of the weed.



Types of gorse seed collection

"Various studies have tried to determine the impacts of seed feeders on gorse seed production and seed banks over the years, but up until now they have lacked the data to describe the reduction in seed fall due to seed predation by the seed-feeding biocontrol agents, and the subsequent impact on gorse infestations," said Paul.

In 2022 the team surveyed two detailed study sites where both of the seed-feeding biocontrol agents were present: one in Christchurch in the South Island and one in Palmerston North in the south-east of the North Island. At each site 15 gorse bushes were selected and measurements taken to determine percentage seed predation by counting the number of healthy versus predated seeds from 10 randomly selected shoots per bush. The same bushes were also measured for seed fall per square metre by placing trays under the bushes to catch falling seeds. Also, the number of seeds per square metre stored in the ground (the seed bank) was measured by taking two soil cores under each bush and counting the seeds in each.

This data was then compared with models produced from a study by Richard Hill (MWLR Research Associate) and Mark Rees (Imperial College, UK) in 2001, which predicted that reductions in gorse cover on a landscape scale could occur under various theoretical seed reduction and management scenarios.

This is where it gets a bit complicated. These models found the primary drivers of gorse invasion and cover to be recruitment (the process whereby new individuals are added to the population) and disturbance (a temporary change in environmental conditions that causes a pronounced change in an ecosystem). Gorse requires a lot of seed fall to maintain high recruitment, and when seed fall drops below a certain threshold it can lead to eventual extinction of the population. But this threshold is a moving target and is dependent on disturbance rates in the area. Gorse needs a moderate amount of disturbance in a landscape, such as landslides or tree fall. With too little disturbance there is no new space for seedlings to grow. On the other hand, too much disturbance and gorse can't persevere under the constant change in environment.

There is one more important caveat. These prediction models are also dependent on seedling survival being low. When the models were run with an assumption of high seedling survival, all the scenarios required a very high, and unlikely level of disturbance coupled with a very low, and unlikely, seasonal seed fall, meaning there would be a very narrow set of circumstances that would need to align for local gorse extinction to occur.

Seedling survival rates will be a concern for many sites across New Zealand, but Paul said, "At the Christchurch and Palmerston North sites, where disturbance has been low since earlier fires and clearing of vegetation, the low seedling survival due to rank grass covering the ground means there is the potential for gorse cover to be reduced if the biocontrol agents can achieve a moderate reduction in seed fall."

The recent survey work by the team found that at the Palmerston North site the estimated total seed produced by gorse in a season was 6,908 seeds/$m^{2.}$ There was 24% seed predation by biocontrol agents, which left 5,250 seeds/m2 to reach the ground (seed fall), and this was culminating in a seed bank averaging a whopping 23,695 seeds/m^2. At the Christchurch site the estimated total seed produced was much lower, at 1,072 seeds/m^2, with much higher seed predation by the biocontrol agents at 60%. This leaves an average of 429 seeds/m^2 reaching the ground (seed fall) and is reflected in the seed bank averaging only 4,312 seeds/m^2.

The gorse pod moth accounted for most of the seed predated at the Palmerston North site (17%) while the gorse seed weevil was dominant at the Christchurch site, accounting for 42% of the predated seed.

So, what numbers did the theoretical models predict?

Richard and Mark took an estimated total natural seed production of 8,888 seeds/m^2 at a site and modelled four theoretical seed reduction scenarios: 0% seed fall reduction (8,888 seeds/m2), 50% seed fall reduction (4,444 seeds/m^2), 75% seed fall reduction (2,222 seeds/m^2), and 95% seed fall reduction (444 seeds/m^2).

Under the assumption of low seedling survival, the models showed that if seed fall was below 444 seeds/$m^{2.}$ this could eventually drive a gorse population to extinction, regardless of how much disturbance occurred at the site; whereas if seed fall was greater than 4,444 seeds/m^2, local extinction was only likely if disturbance was also very frequent.

This is good news for the Christchurch site, which probably has low seedling survival. The total seed fall count was only 429 seeds/m^2, which indicates that the population of gorse should reduce over time, assuming there are no changes in seedling survival rates. Unfortunately, for the Palmerston North site, which had 5,250 seeds/m^2, the results were more comparable to the 0–50% (8,888 seeds/m^2, 4,444 seeds/m^2) seed fall reduction models, meaning this site would need a very high level of disturbance and achieve low seedling survival to reduce the gorse population.

Gorse and tagged shoots. Inset: Seed weevil larvae

The work by Paul and his colleagues offers likely outcomes at two sites in New Zealand. Sites throughout the country vary hugely, but managing for low seedling recruitment will be key for obtaining the greatest impact from seed-feeding biocontrol agents. Management practices that kill plants, prevent or substantially reduce subsequent recruitment, and reduce seedling survival will be required to reduce gorse cover, regardless of seed predation levels.

Recent evidence from broom studies suggests that pollinator management could also be critical to gorse seed production and reducing seed banks. Pollination is an area that has been overlooked in the past, but reducing beekeeper access to vulnerable areas, in combination with seed predation by biocontrol agents, may prove critical in areas where reduced seedling survival cannot always be sustained.

Overall, seed-feeding biocontrol agents can help to reduce long-term gorse cover under certain circumstances by driving seed fall below threshold levels. However, good land management decisions will still be required to prevent seedling recruitment or, if there is a disturbance, to target seedlings before they flower.

Further reading

Rees M, Hill RL 2001. Large-scale disturbances, biological control and the dynamics of gorse populations. Journal of Applied Ecology 38, 364–377.

This project is jointly funded by the National Biocontrol Collective and the Ministry for Primary Industries' Sustainable Food and Fibre Futures Fund (Grant #20095) on multi-weed biocontrol.

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Shedding Light on Herbivore Preference

Despite its warm and fuzzy name, woolly nightshade (*Solanum mauritianum)* is anything but! Introduced as a garden plant in the 1800s, woolly nightshade has spread insidiously across our landscapes to become one of New Zealand's worst weeds.

In 2010 a leaf-feeding lace bug (*Gargaphia decoris*) was introduced to take on this noxious weed. However, the variable impact of the lace bug on woolly nightshade since its release has been a bit of a conundrum. At many localities we struggle to find a single lace bug, yet at some release sites they have prospered. For example, at Ngapeke, in the western Bay of Plenty, woolly nightshade plants have been heavily attacked and defoliated every year, often resulting in plant death.

Sites where woolly nightshade lace bugs have flourished have one thing in common: shade. Heavily infested plants are usually found growing in sheltered sites, such as in the understorey and sheltered logging roads of forestry plantations, Plants in full sun are rarely damaged to any great extent – even those growing just outside the forest a short distance from heavily infested shaded plants at Ngapeke.

Why attack is confined to shady sites has been a mystery, Quentin Paynter explained. "We first suspected that predators, or perhaps parasitoids, were more abundant in sunny sites compared to shady sites," he said. "But we found that predatory insects, such as lacewings, ladybirds, and ants, really weren't very common when we sampled woolly nightshade plants in the shade or in the sun, and we didn't rear a single parasitoid from adult lace bugs, their nymphs, or their eggs," he added.

The potential for birds to feed on the lace bugs was also considered, but there were plenty of fantails at the shady Ngapeke site, so that didn't seem a likely explanation either.

We really were in the dark until a recent publication by Cecilia (Ceci) Falla and her co-authors shed some light on the issue and provided a compelling explanation. Ceci, who was enrolled for a PhD at Massey University, tested the effects of low shade and high shade on the physical and chemical traits of woolly nightshade and the performance of the lace bug under glasshouse conditions.

Ceci measuring light intensity

Ceci found that the leaves of plants under low-shade conditions were smaller, thicker, had longer trichomes (defensive hairs), lower water content, and lower specific leaf area compared to high-shade leaves. Leaves of low-shade plants also increased their carbon to nitrogen (C:N) ratio at a faster rate as they aged, and had a higher total glycoalkaloid concentration than high-shade plants.

Nitrogen is a key element for insect development, and if the C:N ratio in their food increases, they get less nitrogen per 'mouthful'. This can affect growth, survival and development time. Glycoalkaloids are compounds that contribute to the defence response of plants against herbivore attack. "Therefore, one might predict that the leaf chemistry of shaded plants should be more suitable to herbivores, compared to plants growing in full sun," said Ceci.

Ceci found that woolly nightshade lace bugs initially showed no discrimination between high-shade and low-shade leaves for oviposition or feeding. However, second generation females on the same (now older) plants failed to oviposit on the low-shade plants and had smaller bodies compared to the females that developed feeding on the high-shade plants. Ceci and co-authors concluded that light intensity affects both the physical and chemical traits of woolly nightshade plants as the plants age, and these effects influence lace bug performance.

Although the key factor behind the differential performance of the woolly nightshade lace bug under contrasting light conditions remains unclear, the chronic impact suggests that differences in leaf chemistry, rather than physical defences, contribute to the variability of lace bug performance. The ongoing implication of this phenomenon is that additional natural enemies are probably required to fill this gap for the woolly nightshade programme to achieve effective control.

Further reading:

Falla C, Minor M, Harrington K, Paynter Q, Cordiner S, Najar-Roriguez A 2023. Effects of light intensity on *Solanum mauritianum* (Solanaceae) morphological and chemical traits and the performance of its biological control agent *Gargaphia decoris* (Hemiptera: Tingidae). Biological Control 181: 105218.

This research was funded by a PhD Scholarship of the New Zealand Ministry of Foreign Affairs and Trade (MFAT), and MWLR's Beating Weeds Programme, funded by the Ministry of Business, Innovation and Employment's Strategic Science Investment Fund (SSIF).

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Mutualism, Malaysia and Molecular Biology

In 2019, MWLR's weed biocontrol team decided to take a page from the biologist's textbook when looking for collaborators to assist with developing weed biocontrol agents for novel targets in Vanuatu. Mutualism refers to a situation when two entities form a relationship that is mutually beneficial to both parties. The weed biocontrol team was needing to complete surveys and collect leaf material and potential agents in Malaysia for some key pasture weeds in Vanuatu and the wider Pacific as part of the Managing Invasive Species for Climate Change Adaptation in the Pacific (MISCCAP) project. In their search for collaborators, they encountered Dr Nor Asiah Binti Ismail and Ms Nurin Izzati Binti Mohd Zulkifli, from the Malaysian Agricultural Research and Development Institute (MARDI). MARDI was on the search for weed biocontrol experts specifically with molecular knowledge that could help them expand their own molecular capabilities within their weed biocontrol program in Malaysia.

The Malaysian agricultural system is still highly reliant on herbicide use. The need to switch to a more environmentally friendly, targeted and effective long-term alternative has seen a rise in the utilisation of biocontrol, but there is currently no molecular component to support this work. Using molecular tools to match weed genotypes to source locations in the native range is an important step in biocontrol because it can increase the likelihood of finding suitable agents that will successfully attack the target weeds. Genetically identifying the species to be used as potential control agents is also an important complement to morphological identification.

It was a perfect match. MARDI had the resources and expertise available to assist with the weed biocontrol teams MISCCAP project requirements and MWLR had the skills and expertise to help MARDI step up into the molecular space.

For the past few years Asiah and Nurin have been assisting MWLR with work on two target weeds (*Urena lobata and Senna tora/Senna obtusifolia*), which are having a devastating impact on the beef industry in Vanuatu as they outcompete pasture. They have also assisted with research on *Epipremnum pinnatum* cv *aureum* which has dominated native forests and destroyed native ecosystems on many Pacific islands.

Arnaud providing training in the containment facility

Nurin, Caroline and Asiah (left to right)

Last December, Asiah and Nurin were finally able to fly to New Zealand to visit MWLR and learn some new techniques and technology they can take back to their laboratories in Malaysia.

The pair were welcomed at the MWLR Lincoln site by the Biocontrol & Molecular Ecology team. Caroline Mitchell provided the duo with training on plant genotyping techniques and molecular methods to identify insect species. These skills will enable MARDI to perform DNA extractions from potential invertebrate agents and molecularly identify them though sequencing the COI gene (a highly efficient and commonly used gene region for discriminating invertebrate species), rather than relying on potentially inaccurate morphological identification. Building on the laboratory and bioinformatic skills learnt around microsatellite analysis (highly variable regions of DNA that allow for population level discrimination) will enable comparison of plant populations between invasive and non-invasive locations, which reveals important weed invasion information such as potential invasion pathways, sources of introduced material, number of introduction events, level of diversity within the introduced material, and whether material has hybridised in the new region. Knowledge of these factors is key to maximising the success of a biocontrol agent.

Arnaud Cartier also explained the insect rearing and host specificity testing process under containment conditions used here in New Zealand, which ensures safety against attack of non-target organisms.

The molecular skills gained through this training session at MWLR will enable MARDI to build on their capability in this area, leading to improved biocontrol outcomes for Malaysia. Overall, this exchange of knowledge and resources has deepened connections between MWLR and our Malaysian collaborators as well as enhanced both our capabilities. A thoroughly rewarding mutualism indeed.

This project was funded by the Ministry of Foreign Affairs and Trade through the Vanuatu Weeds Project.

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Spring Activities

Most biocontrol agents become active during spring, making it a busy time of year to check release sites and move agents around.

Broom shoot moth *(Agonopterix assimilella)*

- We are unsure if this moth has managed to successfully establish in New Zealand, so we will be interested to hear if anyone can find any sign of them. Late spring is the best time to check release sites, so look for the caterpillars' feeding shelters made by webbing twigs together. Small caterpillars are dark reddish-brown and turn dark green as they get older.

Darwin's barberry weevil *(Berberidicola exaratus)*

- Establishment has been confirmed in Southland and the Greater Wellington region. High densities were found only in Southland where they are currently redistributing the weevils to new sites.
- Beat plants at release sites later in the spring to see if any of the small (3–4 mm long), blackish adults can be found. Also examine the fruits for signs of puncturing. Please let us know what you find.

Giant reed gall wasp *(Tetramesa romana)*

- We don't know if the gall wasp is successfully establishing in New Zealand, so we will be interested to hear about updates from release sites. Look for swellings on the stems caused by the gall wasps. These look like small corn cobs on large, vigorous stems, or like broadened, deformed shoot tips when side shoots are attacked. The galls often have small, circular exit holes made by emerging wasps.
- It will probably be too soon to consider harvesting and redistribution if you do see evidence of the gall wasp establishing.

Honshu white admiral *(Limenitis glorifica)*

- Look for the adult butterflies at release sites from late spring. Look also for pale yellow eggs laid singly on the upper and lower surfaces of the leaves, and for the caterpillars. When small, the caterpillars are brown and found at the tips of leaves, where they construct pontoon-like extensions to the mid-rib. As they grow, the caterpillars turn green with spiky, brown, horn-like protrusions.
- Unless you find lots of caterpillars, don't consider harvesting and redistribution activities. You will need to aim to shift at least 1,000 caterpillars to start new sites. The butterflies are strong fliers and are likely to disperse quite rapidly without any assistance.

Lantana leaf rust *(Prospodium tuberculatum)*

- Check sites where the leaf rust has been released, especially after a period of warm, wet weather. Look for yellowing on the leaves, with corresponding brown pustules and spores, rather like small coffee granules. A hand lens may be needed to see the symptoms during early stages of infection. If the rust is well established, then extensive defoliation may be obvious.
- Once established, this rust is likely to be readily dispersed by the wind. If redistribution efforts are needed, the best method is to harvest infected leaves, wash them in water to make a spore solution, and then apply this to plants.

Moth plant beetle *(Freudeita cupripennis)*

- This beetle has established in the Bay of Plenty and Waikato. Look for adult beetles on the foliage and stems of moth plant. The adults are about 10 mm long with metallic orangey-red elytra (wings cases) and a black head, thorax, and legs. The larvae feed on the roots of moth plant so you won't find them easily.
- The beetles can be harvested if you find them in good numbers. Aim to shift at least 100 beetles to sites that are not yet infested with the beetle.

Privet lace bug *(Leptoypha hospita)*

- Examine the undersides of leaves for the adults and nymphs, especially leaves showing signs of bleaching.
- If large numbers are found, cut infested leaf material and put it in chilly bin or large paper rubbish bag, and tie or wedge this material into Chinese privet at new sites. Aim to shift at least 1,000 individuals to each new site.

Ragwort plume moth *(Platyptilia isodactyla)*

- October is the best time to check release sites for caterpillars, so look for plants with wilted, blackened or blemished shoots with holes, and an accumulation of debris, frass or silken webbing. Pull back the leaves at the crown of damaged plants to look for large, hairy green larvae and pupae. Also check where the leaves join bolting stems for holes and frass. Don't get confused by larvae of the blue stem borer (*Patagoniodes farinaria*), which look similar to plume moth larvae until they develop their distinctive bluish coloration.
- If the moth is present in good numbers, the best time to shift it around is in late spring. Dig up damaged plants, roots and all. Pupae may be in the surrounding soil so retain as much as possible. Shift at least 50–100 plants, but the more the better. Place one or two infested plants beside a healthy ragwort plant so that any caterpillars can crawl across.

Tradescantia leaf, stem and tip beetles *(Neolema ogloblini, Lema basicostata, N. abbreviata)*

- Look for the distinctive feeding damage of the adult beetles and larvae on the stems and leaves of tradescantia.

For the leaf and tip beetles, look for the external-feeding larvae which have a distinctive faecal shield on their backs.

- If you find them in good numbers, aim to collect and shift at least 100–200 beetles using a suction device or a small net. For stem beetles it might be easier to harvest infested material and wedge this into tradescantia at new sites (but make sure you have an exemption from MPI that allows you to do this).

Tradescantia yellow leaf spot *(Kordyana brasiliensis)*

- The smut fungus is now well established in many parts of the North Island. Look for the distinctive yellow spots on the upper surface of the leaves with corresponding white spots underneath, especially after wet, humid weather. Feel free to take a photo to send to us for confirmation if you are unsure, as occasionally other pathogens do damage tradescantia leaves.
- The fungus is likely to disperse readily via spores on air currents. If human-assisted distribution is needed in the future, again you will need permission from MPI to propagate and transport tradescantia plants. These plants can then be put out at sites where the fungus is present until they show signs of infection, and then planted out at new sites.

Tutsan beetle *(Chrysolina abchasica)*

- It is early days for most tutsan beetle release sites, but the best time to look for this agent is spring through to mid-summer. Look for leaves with notched edges or whole leaves that have been eaten away. The iridescent purple adults are around 10–15 mm in size, but they spend most of the day hiding away so the damage may be easier to spot. Look also for the creamy-coloured larvae, which are often on the underside of the leaves. They turn bright green just before they pupate.

Tutsan moth *(Lathronympha strigana)*

- We don't yet know if the tutsan moth has established so are keen to hear if anyone can find them. Look for the small orange adults flying about flowering tutsan plants. They have a similar look and corkscrew flight pattern to the gorse pod moth (*Cydia succedana*). Look also for fruits infested with the larvae.

Other agents

You might also need to check or distribute the following this spring:

- boneseed leafroller (*Tortrix* s.l. sp. *chrysanthemoides*)
- broom gall mites (*Aceria genistae*)
- broom leaf beetle (*Gonioctena olivacea*)
- gorse soft shoot moth (*Agonopterix ulicetella*)
- gorse thrips (*Sericothrips staphylinus*)

Privet lace bug

- gorse colonial hard shoot moth (*Pempelia genistella*)
- green thistle beetle (*Cassida rubiginosa*).

National Assessment Protocol

For those taking part in the National Assessment Protocol, spring is the appropriate time to check for establishment and/or to assess population damage levels for the species listed in the table below. You can find out more information about the protocol and instructions for each agent at: www.landcareresearch.co.nz/publications/books/biocontrol-of-weeds-book

Target	When	Agents
Broom	Oct–Nov Oct–Nov Sept–Oct Aug–Sept	Leaf beetle (*Gonioctena olivacea*) Psyllid (*Arytainilla spartiophila*) Shootmoth (*Agonopterix assimilella*) Twig miner (*Leucoptera spartifoliella*)
Lantana	Oct–Nov (or March–May)	Blister rust (*Puccinia lantanae*) Leaf rust (*Prospodium tuberculatum*)
Tradescantia	Nov–April Anytime	Leaf beetle (*Neolema ogloblini*) Stem beetle (*Lema basicostata*) Tip beetle (*Neolema abbreviata*) Yellow leaf spot fungus (*Kordyana brasiliensis*)

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Who's Who in Biological Control of Weeds?

Alligator weed beetle (*Agasicles hygrophila*)	Foliage feeder, common, often provides excellent control on static water bodies.
Alligator weed beetle (*Disonycha argentinensis*)	Foliage feeder, released widely in the early 1980s, failed to establish.
Alligator weed moth (*Macrorrhinia endonephele*)	Stem borer, common in some areas, can provide excellent control on static water bodies.
Blackberry rust (*Phragmidium violaceum*)	Leaf rust fungus, self-introduced, common in areas where susceptible plants occur, can be damaging but many plants are resistant.
Boneseed leaf roller (*Tortrix* s.l. sp. "*chrysanthemoides*")	Foliage feeder, established and quite common at some North Island (NI) sites but no significant damage yet, limited by predation and parasitism.
Bridal creeper rust (*Puccinia myrsiphylli*)	Rust fungus, self-introduced, first noticed in 2005, widespread and providing good control.
Broom gall mite (*Aceria genistae*)	Gall former, becoming widespread in some regions, beginning to cause extensive damage to broom at many sites, especially in the South Island (SI).
Broom leaf beetle (*Gonioctena olivacea*)	Foliage feeder, establishment confirmed at sites in both islands but not yet common, impact unknown.
Broom psyllid (*Arytainilla spartiophila*)	Sap sucker, becoming common, some damaging outbreaks seen, but may be limited by predation, impact unknown.
Broom seed beetle (*Bruchidius villosus*)	Seed feeder, common in many areas, now destroying up to 84% of seeds at older release sites.
Broom shoot moth (*Agonopterix assimilella*)	Foliage feeder, recently released at limited sites as difficult to rear, appears to be established in low numbers at perhaps 3 sites.
Broom twig miner (*Leucoptera spartifoliella*)	Stem miner, self-introduced, common, often causes obvious damage.
Stripy broom psyllid (*Arytaina genistae*)	Accidentally introduced, common in Canterbury and spreading north and south. Similar to broom psyllid, but adults and nymphs can be present all year on broom. Impact unknown.
Californian thistle flea beetle (*Altica carduorum*)	Foliage feeder, released widely during the early 1990s, failed to establish.
Californian thistle gall fly (*Urophora cardui*)	Gall former, extremely rare as galls tend to be eaten by sheep, impact unknown.
Californian thistle leaf beetle (*Lema cyanella*)	Foliage feeder, only established at one site near Auckland, where it causes obvious damage and from which it is dispersing, also recently reported in the Hawke's Bay.
Californian thistle rust (*Puccinia punctiformis*)	Systemic rust fungus, self-introduced, common, damage usually not widespread.
Californian thistle stem miner (*Ceratapion onopordi*)	Stem miner, attacks a range of thistles, released at limited sites as difficult to rear, establishment success unknown.
Green thistle beetle (*Cassida rubiginosa*)	Foliage feeder, attacks a range of thistles, released widely and some damaging outbreaks beginning to occur.
Chilean needle grass rust (*Uromyces pencanus*)	Rust fungus, approved for release in 2011 but not released yet, additional testing is underway with 3 native grass species, only SI populations likely to be susceptible.
Darwin's barberry flower bud weevil (*Anthonomus kuscheli*)	Flower bud feeder, approved for release in 2012; reapplication required
Darwin's barberry seed weevil (*Berberidicola exaratus*)	Seed feeder, releases began in 2015, difficult to rear so widespread releases will begin once harvesting from field is possible, establishment confirmed in Southland.
Field horsetail weevil (*Grypus equiseti*)	Foliage and rhizome feeder, field releases began in 2017, establishment is looking likely, further releases ongoing.
Giant reed gall wasp (*Tetramesa romana*)	Stem galler, field releases began in late 2017, establishment confirmed at one release site near Auckland.
Giant reed scale (*Rhizaspidiotus donacis*)	Sap sucker, approved for release in 2017, first field releases made early in 2021, establishment likely at one site in Auckland, further releases planned.
Gorse colonial hard shoot moth (*Pempelia genistella*)	Foliage feeder, from limited releases widely established only in Canterbury, impact unknown, but obvious damage seen at several sites.
Gorse hard shoot moth (*Scythris grandipennis*)	Foliage feeder, failed to establish from a small number released at one site, no further releases planned due to rearing difficulties.
Gorse pod moth (*Cydia succedana*)	Seed feeder, common in many areas, can destroy many seeds in spring but not as effective in autumn, not well synchronised with gorse flowering in some areas.
Gorse seed weevil (*Exapion ulicis*)	Seed feeder, common, destroys many seeds in spring.
Gorse soft shoot moth (*Agonopterix umbellana*)	Foliage feeder, common in parts of the SI with some impressive outbreaks seen, and well established and spreading at a site in Northland, impact unknown.
Gorse spider mite (*Tetranychus lintearius*)	Sap sucker, common, often causes obvious damage, but ability to persist is limited by predation.
Gorse stem miner (*Anisoplaca pytoptera*)	Stem miner, native, common in the SI, often causes obvious damage, lemon tree borer has similar impact in the NI.
Gorse thrips (*Sericothrips staphylinus*)	Sap sucker, common in many areas, impact unknown.
Heather beetle (*Lochmaea suturalis*)	Foliage feeder, has damaged/killed 40,000+ ha heather at Tongariro National Park and Rotorua since 1996, spreading rapidly, uncertain if new strains more suited to high altitude released recently have established.
Hemlock moth (*Agonopterix alstromeriana*)	Foliage feeder, self-introduced, common, often causes severe damage.
Hieracium crown hover fly (*Cheilosia psilophthalma*)	Crown feeder, released at limited sites as difficult to rear, thought unlikely to have established.
Hieracium gall midge (*Macrolabis pilosellae*)	Gall former, established but spreading slowly in the SI, common near Waiouru, where it has reduced host by 18% over 6 years, very damaging in laboratory trials.
Hieracium gall wasp (*Aulacidea subterminalis*)	Gall former, established and spreading well in the SI but more slowly in the NI, appears to be having minimal impact although it reduced stolon length in laboratory trials.
Hieracium plume moth (*Oxyptilus pilosellae*)	Foliage feeder, only released at one site due to rearing difficulties, did not establish.

Hieracium root hover fly [*Cheilosia urbana*] **Hieracium rust** [*Puccinia hieracii* var. *piloselloidarum*]	Root feeder, released at limited sites as difficult to rear, thought unlikely to have established. Leaf rust fungus, self-introduced?, common, causes slight damage to some mouse-ear hawkweed, plants vary in susceptibility.
Horehound clearwing moth [*Chamaesphecia mysinformis*] **Horehound plume moth** [*Wheerleria spilodactylus*]	Root feeder, released at limited sites in late 2018, may have established at low levels at one site in the Mackenzie District. Densities too low to confirm establishment. Foliage feeder, released at limited sites in late 2018, initially thought to have established at sites in North Canterbury and Marlborough, causing obvious damage. Later disappeared from these sites, reintroduction planned in late 2023.
Honshu white admiral [*Limenitis glorifica*] **Japanese honeysuckle stem beetle** [*Oberea shirahatai*]	Foliage feeder, field releases began in 2014, already well established and dispersing from site in the Waikato. Stem miner, field releases began in 2017, rearing ongoing in preparation for more field releases, establishment confirmed at one site in Canterbury.
Lantana blister rust [*Puccinia lantanae*] **Lantana leaf rust** [*Prospodium tuberculatum*] **Lantana plume moth** [*Lantanophaga pusillidactyla*]	Leaf and stem rust fungus, releases began autumn 2015, does not appear to have established to date. Leaf rust fungus, releases began autumn 2015, established well and causing severe defoliation already at several sites in Northland. Flower feeder, self-introduced, host range, distribution and impact unknown.
Mexican devil weed gall fly [*Procecidochares utilis*] **Mexican devil weed leaf fungus** [*Passalora ageratinae*]	Gall former, common, initially high impact but now reduced considerably by Australian parasitic wasp. Leaf fungus, probably accidentally introduced with gall fly in 1958, common and almost certainly having an impact.
Mist flower fungus [*Entyloma ageratinae*] **Mist flower gall fly** [*Procecidochares alani*]	Leaf smut, common and often causes severe damage. Gall former, common now at many sites, in conjunction with the leaf smut provides excellent control of mist flower.
Moth plant beetle [*Freudeita cupripennis*] **Moth plant rust** [*Puccinia araujiae*]	Root and foliage feeder, field releases began in late 2019 and will be on-going, some promising early signs that establishment is likely. Rust fungus, approved for release in 2015 but not released yet as waiting for export permit to be granted.
Nodding thistle crown weevil [*Trichosirocalus horridus]* **Nodding thistle gall fly** [*Urophora solstitialis*] **Nodding thistle receptacle weevil** [*Rhinocyllus conicus*]	Root and crown feeder, becoming common on several thistles, often provides excellent control in conjunction with other thistle agents. Seed feeder, becoming common, can help to provide control in conjunction with other thistle agents. Seed feeder, common on several thistles, can help to provide control of nodding thistle in conjunction with other thistle agents.
Old man's beard bud-galling mite [*Aceria vitalbae*] **Old man's beard leaf fungus** [*Phoma clematidina*] **Old man's beard leaf miner** [*Phytomyza vitalbae*] **Old man's beard sawfly** [*Monophadnus spinolae*]	Gall former, stunts the new growth, approved for release in 2019, first field releases took place in 2021. Establishment confirmed in several regions of the country. Leaf fungus, initially caused noticeable damage but has become rare or died out. Leaf miner, common, damaging outbreaks occasionally seen, but appears to be limited by parasitism. Foliage feeder, limited releases as difficult to rear and only established in low numbers at a site in Nelson, more released in North Canterbury in 2018, establishment confirmed at this site.
Privet lace bug [*Leptoypha hospita*]	Sap sucker, releases began spring 2015, establishment confirmed in Auckland and Waikato, some promising early damage seen already in shaded sites.
Cinnabar moth [*Tyria jacobaeae*] **Ragwort crown-boring moth** [*Cochylis atricapitana*] **Ragwort flea beetle** [*Longitarsus jacobaeae*] **Ragwort plume moth** [*Platyptilia isodactyla*] **Ragwort seed fly** [*Botanophila jacobaeae*]	Foliage feeder, common in some areas, often causes obvious damage. Stem miner and crown borer, released widely, but probably failed to establish. Root and crown feeder, common, provides excellent control in many areas. Stem, crown and root borer, recently released widely, well established and quickly reducing ragwort noticeably at many sites. Seed feeder, established in the central NI, no significant impact.
Greater St John's wort beetle [*Chrysolina quadrigemina*] **Lesser St John's wort beetle** [*Chrysolina hyperici*] **St John's wort gall midge** [*Zeuxidiplosis giardi*]	Foliage feeder, common in some areas, not believed to be as significant as the lesser St John's wort beetle. Foliage feeder, common, nearly always provides excellent control. Gall former, established in the northern SI, often causes severe stunting.
Scotch thistle gall fly [*Urophora stylata*]	Seed feeder, released at limited sites but becoming common, fewer thistles observed at some sites, recent study suggests it can have a significant impact on seed production.
Sydney golden wattle gall wasp [*Trichilogaster acaciaelongifoliae*]	Gall former, released at limited sites in 2022 in Manawatū-Whanganui. Establishment not yet confirmed.
Tradescantia leaf beetle [*Neolema ogloblini*] **Tradescantia stem beetle** [*Lema basicostata*] **Tradescantia tip beetle** [*Neolema abbreviata*] **Tradescantia yellow leaf spot** [*Kordyana brasiliensis*]	Foliage feeder, released widely since 2011, established well and causing major damage at many sites already. Stem borer, releases began in 2012, establishing well with major damage seen at several sites already. Tip feeder, releases began in 2013, appears to be establishing readily, no significant impact observed yet. Leaf fungus, field releases began in 2018 and are continuing, establishment confirmed at several sites and promising damage seen at several sites in the NI.
Tutsan beetle [*Chrysolina abchasica*] **Tutsan moth** [*Lathronympha strigana*]	Foliage feeder, difficult to mass rear in captivity so limited field releases made since 2017, establishment success unknown but some promising signs seen. Foliage and seed pod feeder, field releases began in 2017 with good numbers released widely, establishment success unknown.
Woolly nightshade lace bug Gargaphia decoris]	Sap sucker, established at many sites but only reaches high and damaging densities at shaded sites.

Further Reading

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Moth plant beetle

Biocontrol Agents Released in 2022/2023

Species	Releases made
Honshu white admiral *(Limenitis glorifica)*	4
Moth plant beetle *(Freudeita cupripennis)*	7
Giant reed scale *(Rhizaspidiotus donacis)*	3
Field horsetail weevil *(Grypus equiseti)*	6
Tradescantia yellow leaf spot *(Kordyana brasiliensis)*	7
Old man's beard mite *(Aceria vitalbae)*	21
Total	48