WHAT'S NEW IN
Biological Control of Weeds?

Issue 53 Sep 10

Fungus from privet

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Landcare Research
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Tortoise or Hare: Which Factors Determine Dispersal Rate?

Knowing the rate at which biocontrol agents can disperse could help improve the success of biocontrol programmes, and ensure that resources are spent on the most optimal release strategies. Obviously more releases of slow dispersers should be made, closer together, than rapid dispersers. Unfortunately, for most species their dispersal rates are unknown. However, a recent study shows that it is possible to predict the dispersal ability of biocontrol agents from certain key characteristics.

We predicted that eight characteristics may influence the speed at which a species disperses:

- Fecundity – the number of eggs/offspring produced
- Voltinism – the number of generations the species has a year
- Dispersal mode – e.g. flies, crawls, is blown by the wind
- Taxon – e.g. fly, beetle, bug
- Larval lifestyle – e.g. gall-former, seed-feeder, external feeder
- Habitat – e.g. aquatic or terrestrial
- Parasitoids – diversity of species attacking the agent in its native range
- Time since agent was released.

We searched published studies on weed biocontrol agents from around the world for quantitative data on these characteristics. The literature search found data for 65 arthropod and 11 fungal agents – although there was only fecundity and parasitoid data for a subset of these species. We also classified the biocontrol agents as successful or unsuccessful depending on whether or not the damage they caused the target weed led to a significant decline in its population or biomass. The rates of dispersal were extremely variable – the fastest insect, the alligator weed moth (*Arcola malloi*), moved 400 km/year and the slowest, a scale insect that attacks opuntia cactus (*Dactylopius opuntiae*), only 22 m/year. "Approximately 30% of agents dispersed less than one km in a year, while around 10% dispersed more than 100 km over the same time," said Quentin Paynter, who led the study (see graph).

From these data we constructed a series of models to see which characteristics were most strongly correlated with biocontrol agent dispersal rate. The best model indicated that the most important predictors were taxon, voltinism, habitat, larval lifestyle and parasitoid diversity. "In combination the five characteristics explained 75% of the variability in the dispersal rate for weed biocontrol agents, which is surprisingly good," said Quentin.

Taxon

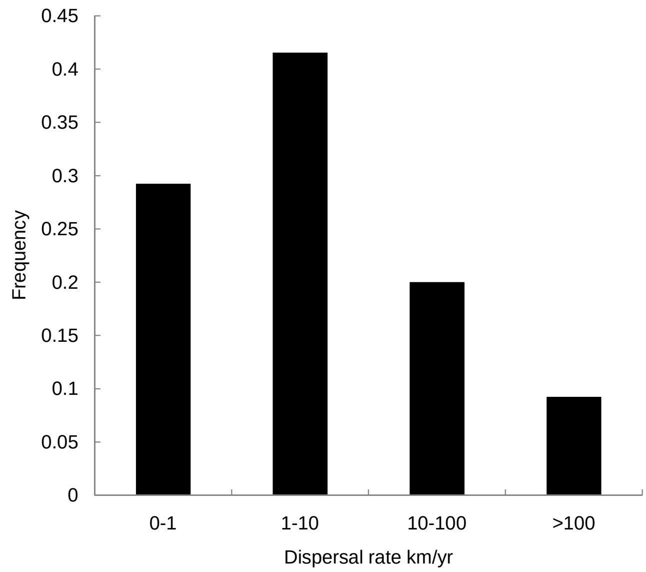
In terms of taxon, flies and moths/butterflies were the fastest dispersers and beetles the slowest. Mites and bugs also dispersed significantly more slowly than flies. However, taxon's importance should be viewed with caution due to the low sample size in the study. Data for only one aphid species was included in the data for bugs – as only one has been released for weed biocontrol – yet aphids can disperse rapidly. If another was used for biocontrol it may disperse more rapidly than the model suggests.

Voltinism

Voltinism was a key factor predicting the dispersal rate of both pathogen and arthropod biocontrol agents. Species with a high number of generations a year have a higher dispersal rate than species with a low number of generations a year. This is likely to be due to a higher rate of population increase: species with many generations are basically capable of reproducing and spreading more rapidly than species with one or two generations per year.

Habitat

Biocontrol agents that attack weeds in freshwater aquatic/wetland habitats dispersed at a faster rate than those that live in terrestrial habitats. A likely explanation is that insects that live in aquatic habitats have undergone selection for good dispersal ability because they exploit ephemeral habitats. Agents living in aquatic habitats are at risk of drying out during droughts or becoming washed away by floods. The alligator weed beetle (*Agasicles hygrophila*), for example, does well



Frequency of dispersal rates of arthropod weed biocontrol agents.

on plants in standing water but often gets washed away in running water and likes humidity so does not do well when its habitat dries out.

Larval lifestyle

In terms of the lifestyle of the larval stage, boring, mining, and leaf-rolling species were generally fast dispersers, especially compared with root and rosette-feeders. It is not entirely clear why this characteristic is important but it may prove to be an indirect measure of parasitism (see below).

Parasitoids

There was a strong positive relationship between the diversity of parasitoids attacking a species in its native range and its dispersal rate. Species with many parasitoids were faster dispersers. One explanation is that species that are heavily parasitised have to be continually "on the run" to escape the pressure. Another explanation is that when a heavily parasitised species is introduced into a new range it is released from the pressure of its native parasitoids and thus does better (the Enemy Release Hypothesis). As mentioned above, parasitoid diversity also varied significantly according to larval lifestyle and taxon. The same lifestyle categories that are the faster dispersers are also the most heavily parasitised.

We tested the accuracy of the best model by using it to predict the dispersal rates of seven international examples of accidentally introduced insects, for which we know the dispersal rates. The predicted rates were generally close to the actual rates with the exception of two species: one which dispersed slower and one faster. The emerald ash-borer (*Agrilus planipennis*) disperses faster than predicted by the model and this discrepancy is most likely explained by the influence of human activity. Significant numbers of the wood-boring beetle are moved greater distances than it would spread naturally by people collecting firewood from infested areas. This instance serves as a good reminder that human activity may need to be taken into account when looking at the dispersal mechanisms of some species.

Having determined the predictors of biocontrol agent dispersal rate, we can look at the question: are fast dispersers better at controlling their target weed than slow dispersers? "Both successful and unsuccessful arthropod and pathogen agents were equally likely to be fast or slow dispersers," said Quentin. Dispersal rate does not affect an agents' success. Both the slowest-dispersing insect (*Dactylopius opuntiae*) and

Alligator weed beetles live in ephemeral habitats and need to be good dispersers.

pathogen (*Puccinia myrsiphylli*) agents are very successful at suppressing their target weeds. This shows that it is worthwhile helping slow dispersers along, using resources such as dispersal data to help optimise release strategies.

The results of this study can also help predict whether a biocontrol agent is likely to persist in highly disturbed environments. At such sites species need to be good dispersers to find suitable habitat and to be able to reinvade areas. Likewise, these results can be applied to predicting the dispersal rate of invasive insects.

While the model we developed was good at predicting dispersal rates, it could be improved. Because data were not available on all characteristics for all species, the strength of some conclusions is limited. Often voltinism data were from the agents' native range and may not necessarily reflect the case in the introduced range. Other voltinism figures were calculated using simplistic estimates. Dispersal rate can also change over time, depending on factors such as food availability. The impact of natural enemies also requires further research. Published data on parasitoids were not found for all arthropod species, and predators and disease (which were not included in the study) are also certain to have an impact.

This study was funded by the Foundation for Research, Science and Technology as part of the Undermining Weeds programme (C10X0811).

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Endophytes: Invisible But Important?

Endophytes are symptomless fungal microbes that live inside plants. All plants have them. It is thought that these associations are very specialised, with the endophytes and their hosts having evolved together over a long period of time. If a plant becomes separated from its endophytes, for example if it is transferred into a new environment as seed, it may do better than in its home range because it retains the nutrients that the endophyte would otherwise have consumed. However, the absence of compounds produced by the endophyte that benefit the plant may also mean that it has lower environmental tolerances and/or lower resistance to pests and diseases, such as biocontrol agents.

Dr Harry Evans (CABI Europe - UK) has proposed that mutualistic endophytes may play an important role in determining whether introduced plants become invasive or not (see *Endophyte Release Hypothesis*, Issue 41). "Should a plant arrive in a new location having escaped its natural enemies but with its endophytes (or if it forms new mutualistic relationships with indigenous endophytes) it would have a greater resistance to natural enemies and environmental factors, and thus a competitive advantage," explained Sarah Dodd. On the other hand plants without endophytes may also have a competitive advantage as they don't have to share their resources so have more to use on growth and reproduction. These two possible outcomes can help explain why classical biocontrol does not always have the impact expected. Weeds that have retained their endophytes might be protected from introduced natural enemies, including biocontrol agents. Weeds without endophytes, by contrast, might be more vulnerable to introduced natural enemies, so biocontrol could have a huge impact on them.

With these ideas in mind we have started investigating what endophytes are present in weeds in New Zealand, as this has not been studied before. The weed we are studying first is Californian thistle (*Cirsium arvense*). We collected tissue samples from the roots, shoots, flowers and seeds of Californian thistle plants at a range of sites, and also from within sites, for comparison. "From this material we have managed to isolate 24 endophyte species by culturing them on agar plates, and by using a molecular technique called DGGE," said Sarah, who is leading the work. Over half of the species were detected using only one method or the other. For example, Basidiomycota fungi, which include rusts, were only detected using DGGE. This shows it is important to use both culturing and molecular methods to detect endophytes.

The endophytes identified include a range of types, from saprobes (which mostly live off dead material) to known pathogens of thistles and other plants, such as grasses. One of the species detected is a rust mycoparasite (*Eudarluca caricis*). The presence of this sort of endophyte, which is a pathogen of rust fungi, could make it difficult for rust diseases to infect the plant. This is significant because rusts often make good biocontrol agents, and it might explain the inconsistent impact of Californian thistle rust (*Puccinia punctiformis*) on the weed. Interestingly, along with Californian thistle rust, rust pathogens of other hosts, such as poplar trees and cultivated chrysanthemum, were also detected. "This is hard to explain as rusts are generally highly host specific. We are now wondering if they can also routinely exist as symptomless endophytes in plants that are not their hosts," suggested Sarah.

Having identified the endophyte community on Californian thistle the next step is to work out whether they are a benefit or a burden to the plant. We have conducted preliminary glasshouse trials to assess the influence of endophytes on the white soft rot fungus (*Sclerotinia sclerotiorum*) disease on Californian thistle. In the field the white soft rot fungus has an inconsistent effect on Californian thistle; some plants are killed completely, others are partially killed and then recover, and some do not appear to be affected at all. Could an endophyte be responsible for this varying result? Plants were inoculated with one of about 20 endophytes collected from the cultures isolated during the sampling process. Once the endophyte was established the plants were infected with white soft rot fungus. Some endophytes had no influence on white soft rot fungus disease, some enhanced the disease, and others,

White soft rot fungus fruiting bodies.

Examples of plants treated with various endophytes and then infected with white soft rot fungus. Some endophytes enhanced the disease, some reduced the disease and others had no impact. *Rebecca Ganley (Scion)*

such as *Colletotrichum acutatum*, reduced the intensity of disease on the plant. "*Colletotrichum* appeared to induce a resistance response in Californian thistle, a bit like immunising it against disease," revealed Sarah.

This work provides evidence that some endophytes do indeed influence the activity of pathogen biocontrol agents. It is likely that they will influence insect biocontrol agents too and this needs to be tested. We plan to continue this work by looking at bacterial endophytes in Californian thistle, identifying the key ways endophytes work, and investigating other weed–endophyte systems, such as old man's beard (*Clematis vitalba*) (particularly in relation to the *Phoma* spp. of leaf fungi), wild ginger (*Hedychium* spp.), privet (*Ligustrum* spp.) and pampas (*Cortaderia selloana* and *C. jubata*). The ultimate aim of this work is to see if we can manipulate the interactions between a weed and its endophytes to improve the consistency of weed biocontrol.

This work was funded by the Foundation for Research, Science and Technology as part of the Undermining Weeds (C10X0811) and Beating Weeds II (C09X0905) projects.

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Biocontrol Agents Released in 2009/10

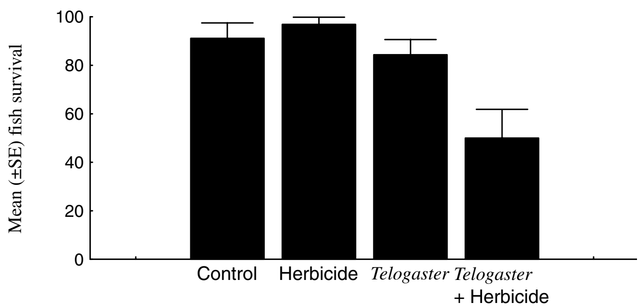
Species	Releases made
Broom leaf beetle (*Gonioctena olivacea*)	6
Broom psyllid (*Arytainilla spartiophila*)	1
Broom shoot moth (*Agonopterix assimilella*)	1
Broom gall mite (*Aceria genistae*)	8
Green thistle beetle (*Cassida rubiginosa*)	19
Californian thistle weevil (*Apion onopordi*)	1
Scotch thistle gall fly (*Urophora stylata*)	1
Ragwort plume moth (*Platyptilia isodactyla*)	9
Gorse soft shoot moth (*Agonopterix ulicetella*)	2
Boneseed leafroller (*Tortrix* s.l. sp. "chrysanthemoides")	4
Total	**52**

More To Herbicides Than Meets The Eye

Natural communities are complex things and no organism occurs in isolation. So when investigating the non-target effects of weed control it is important to look at the wider food web, not just the direct impacts on the target weed itself. Our work on parasitoids (*Is it Possible to Predict Parasitism?* Issue 49) and endophytes (*Endophytes: Invisible But Important?*) is doing just that in relation to biocontrol. Recently, the Wildlife Ecology and Epidemiology Team at Landcare Research looked into the wider effects of herbicide use to control weeds, with some surprising results.

Glyphosate is the most widely used herbicide in the world. Commonly applied in the commercial formulation Roundup®, the chemical is generally considered, at moderate concentrations, to be of low risk to wildlife. The surfactant contained in Roundup is primarily responsible for toxicity. While glyphosate binds to the soil, it can get into waterways through spray drift, surface runoff and/or soil leachate. The study looked at the independent and combined effects of glyphosate and a trematode worm parasite (*Telogaster opisthorchis*) on a threatened native freshwater fish, the roundhead galaxias (*Galaxias anomalus*).

In laboratory trials, fish were exposed to low levels of glyphosate in the presence and absence of an intermediate host of the trematode parasite, an aquatic snail (*Potamopyrgus antipodarum*). The concentration of glyphosate used in the trial (0.36 mg/L a.i.) was one considered safe for wildlife. It is within the limits set for New Zealand freshwaters by the Environmental Risk Management Authority (ERMA) and is well below the levels used in toxicity testing in fish.



Fish survival in the different treatments (*Telogaster* is the trematode worm parasite).

Malformed fish due to parasite infection.

David Kelly

As expected, fish exposed to the parasite, alone or in combination with glyphosate, had significantly higher incidence of infection and damage (spinal malformation) than those in controls or those only exposed to the herbicide. "In terms of fish survival, there was no significant difference between those exposed to either the herbicide or parasite alone or the controls exposed to neither. However, when fish were exposed to the herbicide and parasite together, their survival dropped significantly," explained Dan Tompkins. It appears that low levels of glyphosate had the unexpected impact of making the fish more vulnerable to the parasite.

These findings raise several concerns. First of all, the combined effects of the herbicide and the parasite were not predictable from the results of the individual treatments. Secondly, the conditions used in the experiment would be commonly encountered by fish in the wild. The concentration of glyphosate used in the trial is recommended as safe and is regularly recorded in the environment. In addition, the trematode worm parasite is a common infection of freshwater fish. Thirdly, the timing of glyphosate application may exacerbate this synergistic effect of herbicide and the parasite on fish survival. Glyphosate is often used in spring when juvenile fish are highly susceptible to environmental stressors. Anything which has a significant effect on them will have repercussions for the whole population, and the ecosystem they live in. Finally, this work shows that conventional ecotoxicity testing of herbicides in the laboratory may be too simplified and show different results to what can actually happen in real life.

It is impossible to replicate the "real" world with all its complex interactions in the laboratory but this study shows the importance of testing a pesticide in the presence of organisms from a broader range of trophic levels before it is used widely in the environment.

This work was funded by the Royal Society of New Zealand Marsden Fund.

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Is Nodding Thistle Crown Weevil Size Variable?

Crown weevils in infested rosette. *Bridget Keenan*

It is not unusual for a biocontrol agent to initially establish more readily in some areas than others. However, if it continues to do poorly in an area it is worth investigating why and whether something can be done to improve its performance.

The nodding thistle crown weevil (*Trichosirocalus horridus*) was introduced in 1982 with widespread releases throughout New Zealand over the following decade. While it can dramatically reduce nodding thistle (*Carduus nutans*) infestations, in conjunction with other thistle biocontrol agents, the crown weevil has been extremely slow to get on top of thistles in the high country around Taihape and Taumarunui, in the Manawatu-Wanganui Region. It was thought that weevil populations had remained low there. Because of difficulties harvesting sufficient numbers of adult weevils in the field, Horizons Regional Council staff had been sourcing additional releases from other regions and in doing so noticed differences in weevil size. Crown weevils from Hawke's Bay, for example, appeared to be much smaller than those from Canterbury. The size of herbivorous insects can be influenced by many factors including their genetic heritage and the nutritional status of plants, and the size of biocontrol agents can be a critical factor in their effectiveness.

Given that all the crown weevils in New Zealand came from one original source population major genetic differences between populations here seemed unlikely. So we conducted a study to check if the size differences were significant and if they affected the weevil's impact. Data on larval density, adult size and weight, and the nitrogen and phosphorus content of thistle plants were collected from seven regions where the crown weevil has established (Manawatu-Wanganui, Bay of Plenty, Hawke's Bay, Wellington, Tasman, Canterbury, and Southland).

As it turned out crown weevils in the Manawatu-Wanganui Region compared favourably with those from other regions. "The sites studied in the region showed high densities of weevil larvae, low thistle abundance and smaller thistles compared to other parts of the country," explained Ronny Groenteman, who undertook the study. In terms of size, weevils were either similar or smaller than those from the rest of the country, but those that were smaller did not necessarily weigh less. These differences were more apparent in autumn-collected weevils than in early-summer-collected weevils.

However, the autumn sampling could have been biased by several factors. Small weevils may have been more common in early autumn because they emerged sooner from summer aestivation due to depleting fat reserves faster. Alternatively, larger weevils may have better dispersal ability and be less common for that reason.

In terms of plant nutritional quality there were no clear and consistent relationships between nitrogen concentration in thistles and weevil size. Nitrogen levels may be correlated with adult weevil dry weight but not with size. Similarly, lower phosphorus levels were to some degree correlated with smaller weevils. However, larval density must also be taken into account as high density leads to competition within the crown and can also result in smaller adult size.

This study did not pick up any clear patterns about crown weevil size that could help improve its performance in the Manawatu-Wanganui Region. In fact, it questioned whether the weevil is really doing so badly in the area. A much more detailed study would be required to tease out what appears to be a complex situation. However, such a study would be expensive and resources may be better spent on other agents such as the green thistle beetle (*Cassida rubignosa*).

The results show that there is still some value in releasing the crown weevil in areas where it is not yet present, and for Manawatu-Wanganui there is no advantage in sourcing weevils from outside the region. "However, weevil collection should take place in mid- to late autumn to give larger weevils plenty of time to emerge from aestivation," concluded Ronny.

This project was funded by an Envirolink medium advice grant (HZLC73).

Thanks to the people who provided material for the study: Malinda Matthewson and Don Clark (Horizons), Des Pooley (Bay of Plenty), Darin Underhill (Hawke's Bay), Harvey Phillips (Greater Wellington), Robin Van Zoelen and Lindsay Grueber (Tasman), Jesse Bythell and Peter Ayson (Southland).

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What Does Climate Change Mean For Weed Biocontrol?

Climate change seems to be constantly in the news these days. The majority view among scientists is that there is now enough scientific evidence to be certain that climate change is occurring. A number of possible future scenarios have been modelled that offer a useful starting point for thinking about how our world may change in years to come (see box below). As a result many organisations are considering how they should be preparing for climate change and acting to mitigate its effects. To this end biocontrol experts from the land-based sectors have been collaborating over the past six months in a MAF Policy-funded project to evaluate what climate change might mean for productive-sector biocontrol systems in New Zealand over the next 100 years, in particular asking whether current successful biocontrol regimes could be disrupted, and if so what could be done about this?

Projected changes for New Zealand by 2090 under a mid-range scenario

- Mean air and sea temperatures will increase by around 2°C.
- There will be fewer frosts and more higher-temperature episodes.
- More rain is expected for Tasman, West Coast, Otago and Southland while Northland, Auckland, Gisborne and Hawke's Bay will be drier.
- There will be more extreme rainfall events, especially where rainfall is predicted to increase.
- Snow won't lie around as long, and the snowline will rise.
- There will be a 10% increase in westerly winds. Severe wind events are also more possible.
- Sea level will rise 18–59 cm, and there will be more heavy swells and storm surges.

For more information see www.mfe.govt.nz/publications/climate/index.html

Agroecosystems are complicated so there was quite a lot for the scientists involved to get their heads around. For example an integrated pest management system for growing vegetables needs to consider the effects of climate change on not just the crops, but also the pests of those crops, the suite of predators and parasitoids that are used to control the pests, and the organisms such as hyperparasites that can disrupt these biocontrol agents. In theory mathematically modelling such a system could help us to move beyond mere arm waving, but in practice the data needed to do such modelling are not usually available. It would take many years and many dollars to collect the data to model the system described above! The project team therefore had to identify some more simple examples where there is currently enough data to at least begin to make some predictions, and ragwort biocontrol was selected as one case study.

Ragwort (*Jacobaea vulgaris*) occurs in all regions of New Zealand, but is now well controlled in many situations by the ragwort flea beetle (*Longitarsus jacobaeae*). However, changing rainfall patterns could alter the status quo: ragwort doesn't mind wet feet, but ragwort flea beetles are not effective once rainfall gets high (over 1670 mm/year according to our model). So if some areas get drier then ragwort control may improve and if other areas get wetter, ragwort biocontrol could break down. In other words there could be some gains and some losses (see map). In particular, areas where biocontrol of ragwort is successful are likely to expand (i.e. in eastern North Island), but conversely areas where rainfall is too high for successful suppression of ragwort (i.e. in western South Island and North Island) are likely to increase. Overall the amount of land where ragwort biocontrol could deteriorate is around 315,000 ha (although our model does not consider land use, so clearly the real figure of likely affected pasture will be considerably less than this, and could only be estimated by more detailed modelling).

Another factor that makes this scenario a bit simplistic is the recent release of the ragwort plume moth (*Platyptilia isodactyla*) to improve ragwort control in wetter areas. It is too soon to know how successful the plume moth might be, but it is possible that it may be able to exert control in areas where the flea beetle cannot, in which case ragwort would remain well controlled regardless of climate change. There may also be other ragwort agents available in the native range that could be used to restore control again.

"Warmer temperatures and fewer frosts could mean that ragwort is able to grow at higher altitudes (particularly if pastoral farming extends to higher altitudes), which could affect some of our native *Senecio* species," warns Simon Fowler. Herbarium records show that the range of these native *Senecio* species has shrunk over the past century and they have become rare since ragwort became common. Ragwort may have displaced these plants by simply outcompeting them or through increasing the effects of predation by the native magpie moth (*Nyctemera annulata*). The magpie moth is also able to attack ragwort, and when such an abundant food source suddenly became available magpie moth populations would have been able to increase, leading to heavier attack on their traditional hosts. A close eye will need to be kept on native senecios that are currently hanging on only in high altitude areas where ragwort cannot grow, in case increased efforts need to be made to protect them in future.

When we considered climate change and weed biocontrol in a more general sense there did not appear to be undue cause for alarm. Generally we would expect that if weeds are able to change their distributions, their biocontrol agents will simply follow, as the changes will not be outside of the acceptable range for them. Also agents can from now on be selected with future conditions in mind. “Warmer temperatures and fewer frosts may even suit some biocontrol agents, like the heather beetle (*Lochmaea suturalis*), better than the current climate,” commented Simon. However, more extreme events like droughts (especially if they occur in spring rather than late summer) could make biocontrol of difficult targets like hawkweeds (*Hieracium* spp.) even more tricky, so this will need to be considered when developing such projects.

It is clear that climate change could affect weed biocontrol systems in many ways. Increased CO_2 in the atmosphere is expected to increase plant productivity, leading to increased biomass, but of lower nutritional value as the amount of nitrogen in the plant material will decrease. Lower plant quality could mean that biocontrol agents do more poorly or, conversely, damage plants more heavily in order to get the nutrition they require. The seasonal phenology of plants is also likely to change. This could also be good or bad depending on whether it causes agents that are currently well synchonised with their hosts (e.g. the broom psyllid (*Arytainilla spartiophila*) with bud burst of broom (*Cytisus scoparius*) in the spring) to get out of synch, or agents that are not currently well synchonised (e.g. gorse pod moth (*Cydia succedana*) with flowering and pod production of gorse (*Ulex europaeus*)) to become better aligned. Such interactions can be monitored, and again additional agents sought if need be.

Overwhelmingly the main thing to plan for is the likely worsening of weed species in New Zealand that are not currently under biocontrol. We know that even without climate change weeds are going to become more problematic as more and more species continue to naturalise or move out of lag phases. Climate change will allow many weed species to naturalise and extend their ranges, such as those that are currently limited by frosts. Some of these new weed problems may be able to be nipped in the bud by improved surveillance, or neutralised in pre-emptive strikes by releasing biocontrol agents with wider host-ranges for this purpose.

The Ministry of Agriculture and Forestry provided the funding for this project, which was led by AgResearch.

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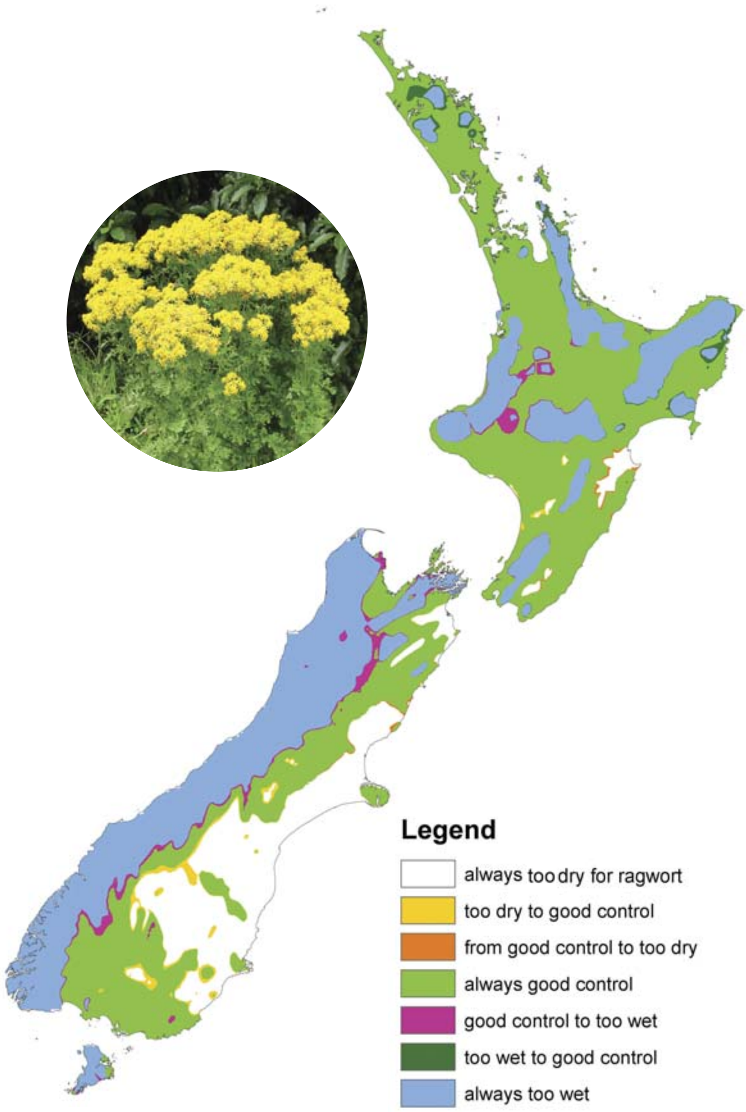

Possible changes in ragwort biocontrol in the future using only the ragwort flea beetle.

Japanese Knotweed in the UK

Authorities in the UK have given the go-ahead for the release of the first ever weed biocontrol agent there. The Japanese knotweed psyllid (*Aphalara itadori*) has this honour and will also be the first classical biocontrol agent officially released for weed control in the European Union (EU). One of the reasons that the UK lags behind New Zealand is that they lack the long history of using natural enemies for weed biocontrol and therefore lack an inherent understanding of the potential of this approach. Also their continental-type flora is considered less vulnerable to weed invasion, as is their extensively managed landscape. To compound this, the general public has had the misconception that the cane toad is a typical biocontrol agent and this has taken some time to overcome.

Japanese knotweed (*Fallopia japonica*), also known as Asiatic knotweed, was introduced into the UK as an expensive ornamental plant by the Victorians and became naturalised in the 1880s. Since then the fast-growing weed has taken off, forming dense thickets up to 3 m tall in as many months and smothering native vegetation. In addition to the impacts on native plants and animals – which include reduced species diversity – it causes damage to built environments. "The weed has a well-deserved reputation as a 'concrete cracking superweed' as its strong rhizomes (underground stems) can push through asphalt, concrete and drains," said Dick Shaw, CABI Europe - UK lead researcher on the project. The characteristic that makes it the most difficult to get rid of, however, is its ability to regrow from tiny fragments of rhizome. Even pieces weighing less than one gram can resprout. This ability, coupled with an extensive rhizome system, makes it extremely difficult to be sure that the entire weed has been killed when dealing with an infestation, and the movement of soil contaminated in this way has helped its spread around the UK (see maps). Japanese knotweed is one of only two terrestrial plants in the UK that are not allowed by law to profligate in the wild, and there are extensive controls on its movement and disposal. Estimates of the costs to control and clear Japanese knotweed from the whole UK are £1.56 billion (10^{12}) and it is believed to cost the economy over £150m a year.

Surveys of the natural enemies of Japanese knotweed in its home range found 186 plant-feeding arthropods and over 40 species of fungi attacking the plant. Host-specificity testing cut this down to two potential biocontrol agents, the psyllid and a leafspot fungus (*Mycospaerella polygoni-cuspidati*). "The leafspot is certainly one of the most damaging organisms we found in Japan but its life cycle makes it challenging to work with," said Dick. Host-testing of the psyllid showed that it is extremely specific, so it has become the priority and work on the leafspot is on the back-burner for the time being.

All life-stages of the psyllid feed on Japanese knotweed but the nymphs cause the most significant damage. They feed on the sap thus stunting the plant's growth and inhibiting photosynthesis. The nymphs are sedentary so it was particularly important to test females' preferences for

Spread of Japanese knotweed in the UK (a) 1930, (b) 1970, (c) 2010.
Data from the National Biodiversity Network UK (including Local Records Centres and NIEA).

Japanese knotweed psyllid. *CABI*

egg-laying sites. Fortunately, they showed a huge preference for Japanese knotweed and psyllids could only complete development from egg to adult on invasive knotweeds. Wanting to err on the side of caution, researchers even conducted tests by artificially transferring nymphs onto any non-target plant species that received any eggs to see how they did. Interestingly, the only non-target species on which the psyllid could complete development from nymph through to adult in these tests was wire vine (*Muehlenbeckia complexa*), a native New Zealand creeper that has become invasive on some offshore islands in the UK. Subsequent to this, New Zealand researchers have collected an apparent hybrid between Japanese knotweed and another *Muehlenbeckia* species, as confirmed by John Bailey, the knotweed guru in the UK.

The Japanese knotweed biocontrol researchers have had to go through many regulatory steps to get permission to release the psyllid in the UK. Applications were made under the Wildlife and Countryside Act 1981 and the Plant Health Regulations – which involved a pest risk analysis. The applications were reviewed by the Advisory Committee on Releases to the Environment (ACRE) and peer-reviewed by three experts. After a 3-month public consultation and consideration by the Government's chief Scientist, the UK Government finally gave the approval for restricted release in March, as long as a fully-funded 5-year contingency and monitoring plan was in place. Releases have since been made at a limited number of sites, which are isolated and contain planted specimens of UK species closely related to Japanese knotweed. "We do not expect any non-target attack but, in the unlikely event of the worst happening, we have agreed to have contractors on hand to apply insecticide and herbicide treatments to contain and eradicate it," said Dick. If all goes well, wider releases will be made, but until then intensive fortnightly monitoring is underway at release sites.

This project is of interest to us in New Zealand as we also have Japanese knotweed. It has been here for at least 80 years and is just starting to take off. The weed is not yet common in the North Island but is doing well in south-east Nelson and is abundant in Westland (see map). Giant knotweed (*Fallopia sachalinensis*) and a hybrid knotweed (*Fallopia* × *bohemica*) also grow here but have a more limited distribution. Knowing how invasive Japanese knotweed is in the UK and Europe and the damage that it causes, we will follow this project's progress with interest – it may be that we need to consider biocontrol for Japanese knotweed here in the not too distant future.

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Japanese knotweed.

Spring Activities

Spring is one of the busiest times of the year for biocontrol agents, so there are many activities that you might need to plan for, such as:

Boneseed leafroller (*Tortrix* s.l. sp."*chrysanthemoides*")

- From mid-spring check release sites for the feeding shelters made by caterpillars webbing together leaves at the tips of stems. Small caterpillars are olive-green in colour and become darker with two parallel rows of white spots as they get older. You may encounter a native leafroller species (*Ctenopseustis* sp.) that is a similar colour to the boneseed leafroller, but it does not have the rows of white spots. We would be very interested to hear if you see any severe damage to boneseed foliage.
- You can begin harvesting caterpillars if you find good numbers. Cut off infested boneseed tips and wedge them into plants at new sites. Aim to shift at least 500 caterpillars. Do not release the leafrollers in areas where there are Argentine ants.

Bridal creeper rust (*Puccinia myrsiphylli*)

- Check bridal creeper infestations for bridal creeper rust, especially sites where it has not been seen before. Infected plants will have yellow and black pustules on the undersides of leaves and on the stems and berries. They may look sickly and defoliated.
- If need be you can spread bridal creeper rust around – for detailed instruction on how to do this see www.csiro.au/resources/BridalCreeperRustFungus.

Broom gall mite (*Aceria genistae*)

- Check release sites in spring and summer for galls caused by the broom gall mite. These deformed lumps range in size from 5 to 30 mm across and are likely to be close to the release point. Occasionally galls can be found on broom that are not made by our new biocontrol agent, but these are much less dense. Contact us if you find galls and need help to confirm their identity.
- If you find galls in good numbers you may be able to begin harvesting and redistribution in late summer when the galls are mature. Aim to shift at least 50 galls, and tie them onto plants at the new site so the tiny mites can shift across.

Broom leaf beetles (*Gonioctena olivacea*)

- Check broom leaf beetle release sites, although it might still be early days for finding the beetles at many sites. Adult beetles are 2–5 mm long and males have an orangey-red tinge and females tend to be goldish-brown – although colouration can be quite variable. Larvae are a crocodile shape and you might see them feeding on leaves and shoot tips in late spring. A beating tray is likely to be useful when looking for this agent.
- We would not expect you to find enough beetles to be able to begin harvesting just yet.

Broom seed beetles (*Bruchidius villosus*)

- Look for adults congregating on broom flowers or for eggs on the pods.
- Beetles can be moved around if they are not yet widespread. Collect adults by either beating broom flowers over a sheet and sucking them up with a pooter or putting a large bag over flowers and giving them a good shake. Alternatively, you can harvest infested pods in summer when they are blackish-brown and beginning to burst open.

Broom shoot moth (*Agonopterix assimilella*)

- Check broom shoot moth release sites, although it might still be early days for finding them at most sites. Late spring is the best time to look. Look for

Broom gall mite galls.

Ragwort crown-boring moth larvae.

the caterpillars' feeding shelters made by tying twigs together with webbing and for the caterpillars inside. Small caterpillars are dark brown and turn dark green as they mature.
- We would not expect you to find enough caterpillars to be able to begin harvesting just yet.

Gorse soft shoot moth (*Agonopterix ulicetella*)
- Check release sites in late November or early December when the caterpillars are about half-grown. Look for webbed or deformed growing tips with a dark brown or greyish-green caterpillar inside. Please let us know if you find an outbreak or this agent anywhere that you didn't expect. We would especially like to hear how they are doing in the North Island and lower South Island.
- Caterpillars can be moved around if they are not yet widespread. Harvest infested branches or even whole bushes.

Gorse colonial hard shoot moth (*Pempelia genistella*)
- Check release sites in late spring and when the green-and-brown striped caterpillars and their webs are at their largest, and before plants put on new growth. Please let us know if you find any, anywhere, as we still have only confirmed establishment at a few sites in Canterbury.
- Help is needed to increase the distribution of this moth. If you can find the webs in good numbers, harvest infested branches in late spring when large caterpillars or pupae are present and redistribute.

Green thistle beetles (*Cassida rubiginosa*)
- Check release sites for green thistle beetles – it has been possible to find them at many sites only a year after they were released. Towards the end of winter adults emerge on warm days and feed on new thistle leaves, making round window holes. The adults are green and 6–7.5 mm long, but can be quite well camouflaged against the leaf. The larvae have a protective covering of old moulted skins and excrement. They also make windows in the leaves.
- It may be possible to begin harvesting at some of the oldest release sites this spring. We expect that the best way to collect these beetles will be using a garden-leaf vacuum machine. Aim to shift at least 50 adults in the spring. Be careful to separate them from other material collected during the vacuuming process, which may include pasture pests.

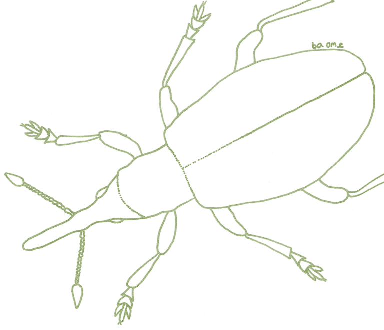
Ragwort crown-boring moth (*Cochylis atricapitana*)
- Check release sites for rosettes with damaged centres and black frass or thickened stems and bunched leaves. The caterpillars are most easily seen by pulling apart damaged plants during August–September. They are quite short and fat, creamy-white, with black heads that become brown when they are older. We would be very pleased to hear of any likely finds as we are not confident that they have established at any sites yet.

Ragwort plume moth (*Platyptilia isodactyla*)
- Check release sites in October for plants with wilted or blackened or blemished shoots. Damaged shoots will also have holes in the stems and an accumulation of debris, frass or silken webbing. The caterpillars are most easily seen by pulling apart damaged plants, and when large are pale green and hairy. Don't get confused with blue stem borer larvae (*Patagoniodes farinaria*), which look similar to plume moth larvae until they develop their distinctive bluish colouration.
- If you can find this moth in good numbers the best time to harvest it is in late spring. Dig up damaged plants, roots and all. Pupae may be in the surrounding soil so retain as much as possible. The more caterpillars and/or pupae you can shift the better, and we recommend shifting at least 50–100 plants. At the release site place one or two infested plants beside a healthy ragwort plant so any caterpillars can crawl across.

Send any reports of interesting, new or unusual sightings to Lynley Hayes (hayesl@landcareresearch.co.nz, Ph 03 321 9694). Monitoring forms for most species can be downloaded from www.landcareresearch.co.nz/research/biocons/weeds/book/ *under Release and Monitoring Forms.*

Who's Who in Biological Control of Weeds?

Alligator weed beetle *(Agasicles hygrophila)* Alligator weed beetle *(Disonycha argentinensis)* Alligator weed moth *(Arcola malloi)*	Foliage feeder, common, often provides excellent control on static water bodies. Foliage feeder, released widely in the early 1980s, failed to establish. Foliage feeder, 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, first released in 2007, establishment confirmed at some North Island sites but no significant damage seen yet.
Bridal creeper rust *(Puccinia myrsiphylli)*	Rust fungus, self-introduced, first noticed in 2005, widespread, appears to be causing severe damage at many sites.
Broom gall mite *(Aceria genistae)* Broom leaf beetle *(Gonioctena olivacea)* Broom psyllid *(Arytainilla spartiophila)* Broom seed beetle *(Bruchidius villosus)* Broom shoot moth *(Agonopterix assimilella)* Broom twig miner *(Leucoptera spartifoliella)*	Gall former, first released at limited sites in late 2007 and establishment has been confirmed at three sites already, widespread releases are continuing. Foliage feeder, first released in 2006/07 and establishment appears likely at one site so far. Widespread releases are continuing. Sap sucker, becoming more common, some damaging outbreaks seen so far but may be limited by predation, impact unknown. Seed feeder, becoming more common, spreading well, showing potential to destroy many seeds. Foliage feeder, first released early in 2008, limited releases made so far and establishment success not yet known, widespread release are continuing. Stem miner, self-introduced, common, often causes obvious damage.
Californian thistle flea beetle *(Altica carduorum)* Californian thistle gall fly *(Urophora cardui)* Californian thistle leaf beetle *(Lema cyanella)* Californian thistle rust *(Puccinia punctiformis)* Californian thistle stem miner *(Ceratapion onopordi)*	Foliage feeder, released widely during the early 1990s, not thought to have established. Gall former, rare, galls tend to be eaten by sheep, impact unknown. Foliage feeder, only established at one site near Auckland where it is causing obvious damage. Further releases may be made from this site. Systemic rust fungus, self-introduced, common, damage not usually widespread. Stem miner, attacks a range of thistles, first released early in 2009, limited releases made so far and establishment success not yet known. Difficult to rear, releases will continue as available.
Green thistle beetle *(Cassida rubiginosa)*	Foliage feeder, attacks a range of thistles, widespread releases began in 2007/08 and are continuing, establishment is looking promising at most sites.
Echium leaf miner *(Dialectica scalariella)*	Leaf miner, self-introduced, becoming common on several *Echium* species, impact unknown.
Gorse colonial hard shoot moth *(Pempelia genistella)* Gorse hard shoot moth *(Scythris grandipennis)* Gorse pod moth *(Cydia succedana)* Gorse seed weevil *(Exapion ulicis)* Gorse soft shoot moth *(Agonopterix umbellana)* Gorse spider mite *(Tetranychus lintearius)* Gorse stem miner *(Anisoplaca pytoptera)* Gorse thrips *(Sericothrips staphylinus)*	Foliage feeder, limited releases to date, established only in Canterbury, impact unknown but obvious damage seen at several sites. Foliage feeder, failed to establish from small number released at one site, no further releases planned due to rearing difficulties. Seed feeder, becoming common, spreading well, can destroy many seeds in spring but is not so effective in autumn and not well synchronised with gorse-flowering in some areas. Seed feeder, common, destroys many seeds in spring. Foliage feeder, becoming common in Marlborough and Canterbury with some impressive outbreaks, establishment success in the North Island poor to date, impact unknown. Sap sucker, common, often causes obvious damage, but persistent damage limited by predation. Stem miner, native insect, common in the South Island, often causes obvious damage, lemon tree borer has similar impact in the North Island. Sap sucker, gradually becoming more common and widespread, impact unknown.
Hemlock moth *(Agonopterix alstromeriana)*	Foliage feeder, self-introduced, common, often causes severe damage.
Hieracium crown hover fly *(Cheilosia psilophthalma)* Hieracium gall midge *(Macrolabis pilosellae)*	Crown feeder, limited releases made so far, establishment success unknown, rearing difficulties need to be overcome to allow widespread releases to begin. Gall former, widely released and has established but is not yet common at sites in both islands, impact unknown but very damaging in laboratory trials.



Hieracium gall wasp *(Aulacidea subterminalis)* Hieracium plume moth *(Oxyptilus pilosellae)* Hieracium root hover fly *(Cheilosia urbana)* Hieracium rust *(Puccinia hieracii* var. *piloselloidarum)*	Gall former, widely released and has established but is not yet common in the South Island, impact unknown but reduces stolon length in laboratory trials. Foliage feeder, only released at one site so far and did not establish, further releases will be made if rearing difficulties can be overcome. Root feeder, limited releases made so far, establishment success unknown, rearing difficulties need to be overcome to allow widespread releases to begin. Leaf rust fungus, self-introduced?, common, may damage mouse-ear hawkweed but plants vary in susceptibility.
Heather beetle *(Lochmaea suturalis)*	Foliage feeder, released widely in Tongariro National Park, some damaging outbreaks now starting to occur, also established near Rotorua and severely damaging heather there.
Lantana plume moth *(Lantanophaga pusillidactyla)*	Flower feeder, self-introduced, distribution and impact unknown.
Mexican devil weed gall fly *(Procecidochares utilis)*	Gall former, common, initially high impact but now reduced considerably by Australian parasitic wasp.
Mist flower fungus *(Entyloma ageratinae)* Mist flower gall fly *(Procecidochares alani)*	Leaf smut, common and often causes severe damage. Gall former, now well established and common at many sites, in conjunction with the leaf smut provides excellent control of mist flower.
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 nodding thistle agents. Seed feeder, becoming common, can help to provide control in conjunction with other nodding thistle agents. Seed feeder, common on several thistles, can help to provide control of nodding thistle in conjunction with the other nodding thistle agents.
Old man's beard leaf fungus *(Phoma clematidina)* Old man's beard leaf miner *(Phytomyza vitalbae)* Old man's beard sawfly *(Monophadnus spinolae)*	Leaf fungus, initially caused noticeable damage but has since either become rare or died out. Leaf miner, common, only one severely damaging outbreak seen, appears to be limited by parasites. Foliage feeder, limited widespread releases have been made, has probably failed to establish.
Phoma leaf blight *(Phoma exigua var. exigua)*	Leaf spot fungus, self-introduced, becoming common, can cause minor–severe damage to a range of thistles.
Scotch thistle gall fly *(Urophora stylata)*	Seed feeder, limited releases to date, appears to be establishing readily, impact unknown.
Tradescantia leaf beetle *(Neolema ogloblini)*	Foliage feeder, permission to release has been granted by ERMA but remaining in quarantine until it can be cleared of a gut parasite.
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, limited number of widespread releases made in 2006/07, but no evidence of establishment yet. Root and crown feeder, common in most areas, often provides excellent control in many areas. Stem, crown and root borer, widespread releases made in past 4 years, appears to be establishing readily and reducing ragwort already at some sites. Seed feeder, established in the central North Island, 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, often provides excellent control. Gall former, established in the northern South Island, often causes severe stunting.
Woolly nightshade lace bug *(Gargaphia decoris)*	Sap sucker, permission to release has been granted by ERMA, releases expected to begin this spring.

Further Reading

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If you want assistance in locating any of the above references please contact Julia Wilson-Davey. *What's New In Biological Control of Weeds?* issues 11-52 are available from the Landcare Research website (www.landcareresearch.co.nz).

www.landcareresearch.co.nz

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Thanks to: Christine Bezar
Design: Cissy Pan

www.weedbusters.org.nz

ISSN 1173-762X (Print) ISSN 1173-8784 (Online)