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General News

Biological Control of Giant Reed along the Rio Grande

An assessment of the first biocontrol agent released against giant reed (*Arundo donax*) in riparian habitats of the lower Rio Grande river in North America indicates that, five years after its introduction, the eurytomid gall wasp is having a significant effect.[1] Pre- and post-release monitoring has revealed clear and fairly consistent changes in giant reed health in the infested riparian habitats between Brownsville and Del Rio, Texas over 558 river miles (~1000 km). Given that giant reed is a clonal grass with large reserves in its extensive and interconnected rhizome, prospects are good for greater impact in the future – especially as a second agent has established and another is in development.

Giant reed is a perennial bamboo-like grass whose Old World native range extends from the Mediterranean region through the Middle East to south Asia. Introduced centuries ago by Spanish colonists to North America as a fibre crop (roof thatching, fencing, etc.) , it has been spread by movement of rhizomes and canes and has become an invasive weed in a number of countries. Giant reed invasion displaces native vegetation, with negative effects on wildlife habitat and river hydrology. Pure stands also present a fire risk and can enhance cattle fever tick survival. Along the lower Rio Grande, which forms the border between Texas and Mexico, the tall (2–10 m), dense thickets present a border security issue. In addition, giant reed consumes large quantities of groundwater, typically three times as much as native vegetation (in Mexico it is known as 'el ladron de agua' – the water thief). Water is a scarce and increasingly limiting resource for the expanding population of the arid Rio Grande basin. The area has experienced recent extended drought and faces changing rainfall patterns under climate change. Mechanical removal and chemical control of giant reed is ineffective and expensive over such a large area, while an economic analysis[2] suggests that successful biological control could not only increase water availability in this part of the Rio Grande basin but also have a benefit–cost ratio of more than 4:1.

A joint US/Mexican initiative that began in 2005 was the first programme worldwide to introduce biocontrol agents against giant reed. Scientists from the US Department of Agriculture (USDA), European Biological Control Laboratory (Montpellier, France) identified several species in Mediterranean Europe that showed sufficient host specificity, and these species were sent to USDA Agricultural Research Service in Edinburg, Texas for host-range testing and biological studies.

The first agent to be released, the arundo gall wasp (*Tetramesa romana*), occurs throughout much of the native range of giant reed. Pre-release efficacy studies in Texas suggested it could have significant impact in the introduced range by stunting growth and killing stems.[3] Aerial release of 1.2 million wasps started in 2009,[4] while the second agent, the arundo scale (*Rhizaspidiotus donacis*), was released in 2011.[5] By 2012 *T. romana* was established along the entire length of the lower Rio Grande from the Amistad Dam at Del Rio to the mouth of the river at Brownsville, Texas – the target area for biological control, and a regulated water environment with steady water flow which has provided ideal habitat for giant reed.

Monitoring studies in Texas compared above-ground standing biomass of giant reed measured pre-introduction in 2007 and five years after *T. romana* was introduced, in 2014, at ten sites containing mature, unmanaged/undisturbed giant reed, which were located approximately every 50 miles (90 km) along the stretch of river between Del Rio and Brownsville. Although there was variation between sites, there was no geographic pattern. Above-ground biomass decreased by an average of 22% between 2007 and 2014, which is estimated to be a loss of 2.5 million tons [1 ton = 0.907 metric tonnes]. Assessments of other plant parameters in 2014 indicated that the decline in giant reed is associated with a reduction in live shoot density and length in giant reed stands and, in particular, is negatively correlated with number of *T. romana* exit holes in main and lateral shoots. Water savings for the USA from the current 22% reduction in giant reed biomass in the lower Rio Grande are estimated at US$4.4 million/year. Declines in giant reed density are also expected to make stands easier to penetrate visually and physically and aid more effective law enforcement, while better light penetration should help regeneration of native riparian vegetation.[6]

The second agent to be established, the armoured scale *R. donacis*, is one of the most widespread and damaging arthropods associated with *A. donax* in the subtropical regions of its native range in Mediterranean Europe,[7] and when stands are undisturbed *R. donacis* has a significant impact on *A. donax* growth. Preliminary results show that the scale is reducing recruitment of new canes, however its six-month life cycle and lack of dispersal ability are limiting its widespread impact. A third agent, the leafsheath-mining cecidomyiid fly *Lasioptera donacis,* has been shown to be host specific and a release petition has been submitted. This agent causes widespread defoliation in Europe and, like *T. romana*, could increase the level of light penetration and thus stimulate growth of native riparian vegetation.

While the recent study is good news for the Rio Grande, it is also promising for other countries considering giant reed biological control. The arundo scale and wasp have been provided to PPRI (Plant

Protection Research Institute) in South Africa and Landcare Research in New Zealand for release. Taking a wider perspective, the impact of the gall wasp on giant reed is an indication that invasive grassy weeds, which have often fallen into the 'too-difficult' category of targets, may be effectively tackled with classical biological control.

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Biological Control of Imported Fire Ants in the USA

South American fire ants in the genus *Solenopsis* are invasive in a number of countries. A recent review article in *Myrmecological News*[1] summarizes current and prospective classical biocontrol agents for the imported fire ants in the USA. Classical biological control programmes began in Florida and Texas in 1994 with the aim of introducing natural enemies from South America. The first two biocontrol agents to be successfully released (two *Pseudacteon* decapitating flies) are now found in most of the invaded US range, six additional agents (four more decapitating flies and two microbial agents) are established. Prospective surveys and research for additional agents continue as technological advances provide new information regarding the origin of imported fire ant populations in the USA, and facilitate discovery of new microbial taxa.[2] US research with fire ant biological control has been ground-breaking because biological control has rarely been considered for invasive ants, perhaps because of the emphasis on eradication, containment and chemical management.

Records indicate that the imported fire ants, *Solenopsis richteri* and *S. invicta,* were accidentally introduced to the southern USA in 1918 and the 1930s, respectively, although they were not designated as separate species until 1972. Both species probably arrived in soil used as ship ballast into the port of Mobile, Alabama. By 2014 they had spread to occupy some 148 million hectares of the southeastern states where they are 5–10 times more abundant than in their native South America. Imported fire ants are a federal quarantine pest[3], with restrictions on the movement of regulated articles from quarantined areas into or through non-quarantined areas. The ants have damaging effects on crops and wildlife, and are an urban nuisance and of medical significance.

From the outset of the US programmes, the knowledge that fire ants in South America are attacked by more than 20 decapitating phorid flies in the genus *Pseudacteon* focused attention on this genus. The female fly lays an egg in the thorax of a worker fire ant. The hatching larva moves into the ant's head capsule to develop. At pre-pupation it releases a chemical that causes the ant's head to detach from its body, and the fly pupates in the head capsule. Extensive research showed that the *Pseudacteon* species exhibit a good level of host specificity. Species found attacking the target species in South America showed a preference for *S. invicta* and the hybrid rather than native North American *Solenopsis* spp. In the case of one species, *P. curvatus*, distinct biotypes were recovered from and showed preference for *S. richteri* and *S. invicta*, respectively. The specificity test results have been borne out by post-release field studies.

The first agent, *Pseudacteon tricuspis*, was introduced and established in 1997, with the two biotypes of *P. curvatus* following suit in 2000 and 2003. A compilation of data from published and unpublished sources[4] revealed that by late 2008 *P. tricuspis* was well-established across some 50% of the US quarantine area, and this was anticipated to reach 65% by 2011 although further spread was expected to be curtailed by slow dispersal and failure to thrive in the northern part of the imported fire ants' distribution. The *P. curvatus* biotypes were collectively found over almost 60% of the quarantine area in 2008 and were expected to cover close to 90% by 2011 and reach 100% in another 1–2 years. Additionally, *P. tricuspis* and/or *P. curvatus* have been released in Puerto Rico. These two species have spread into the Bahama Islands from Florida and *P. curvatus* has spread into the US Virgin Islands, probably from Puerto Rico. (S. Porter, pers. comm.). Four other *Pseudacteon* species have also been established in the USA: *P. litoralis* in 2005, *P. obtusus* in 2006, *P. nocens* in 2006–10 and *P. cutellatus* in 2010. This suite of *Pseudacteon* species was selected to exploit their different activity patterns and host preferences so as to increase pressure on the target species, while hopefully minimizing interspecific competition. The rate of parasitism by the flies is low (at most 5%) and their impact on fire ants is behavioural. The presence of a single fly can stop or greatly inhibit worker foraging. Evidence of field impact so far is equivocal, however, and while the phorids have proliferated in the USA, that may simply reflect an abundance of hosts. Ants may compensate, for example by foraging at night when flies are not present, or using underground tunnels. Nevertheless, there are also other reasons for optimism. Where the biocontrol agents (including pathogens discussed below) are present, although nest numbers are often unaffected, nests themselves tend to be smaller (i.e. have fewer ants).

In addition to the phorids, two pathogens causing debilitating disease were isolated from the target fire ants in both South America and the USA: a microsporidian (*Kneallhazia solenopsae*) detected in Florida in 1996, and an RNA virus, Solenopsis invicta virus 3 (SINV-3). The life cycle of the microsporidian has not yet been fully elucidated but infection causes colony decline and has been shown to reduce field populations in South America and the USA. It has been redistributed from Florida and has established in five other states. Traditional methods had failed to discover pathogenic viruses of fire ant species despite extensive searches in South America. Introduction of the metatranscriptomics approach, however, facilitated the discovery in recent years of four viruses, the first viruses known to infect any ant: three RNA viruses in the USA, and a densovirus in South America. SINV-3, which is associated with significant colony mortality and has been shown to be specific to imported fire ants, is being developed as a biocontrol agent and a biopesticide. Efforts are also being made to develop the densovirus as a classical biocontrol agent. The addition of two, potentially three, microbial agents provides natural, sustained impacts on US fire ant populations.

Other insect and microbial natural enemies are known to reduce vigour in fire ants but are not currently prioritized, and more may be discovered. Thus the possibility of introducing more agents exists, on top of the eight already in the field, whose interactions are being studied. Field evidence to date has found this to be unpredictable for the phorid species, with both displacement and enhancement observed. Microbial agents seem to have no adverse effects on the phorids, and all three types of agent may occur in one colony. This is a research area that is being actively pursued.

Whether biological control can provide complete control of imported fire ants in the USA in the long term remains to be seen, but efficacy is likely to vary between localities – and with perceptions. The goal of this approach is to weaken rather than eliminate colonies, however this provides an opportunity for improving on existing imported fire ant management. Area-wide demonstrations in five states showed that fire ant suppression with biological control + insecticide baits is greater than that afforded by baits alone. Increased persistence of imported fire ant clearance is facilitated by the biocontrol agents weakening the colonies, so that the ants are slower to recolonize.

Almost two decades of research and implementation by the US biological control programmes indicate that classical biological control of invasive ants has potential, both alone and integrated with current approaches, to improve invasive ant management. This is rewarding for those involved in the programmes, while the progress made and knowledge acquired could be immensely useful to scientists in other countries tackling *Solenopsis* and other invasive fire ants.

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Potential of Viruses for Control of Invasive Argentine Ants

A paper in *Biology Letters* reporting on the discovery of two hymenopteran viruses in the Argentine ant (*Linepithema humile*) in New Zealand discusses how these may offer new options for biological control of this global invasive species. It also highlights the neglected issue of invasive species disseminating exotic pathogens to native species.[1]

A metagenomics approach, involving analysis of RNA recovered from environmental samples, led to the identification of a novel virus, *Linepithema humile virus* 1 (LHUV-1). The virus belongs to the Dicistroviridae, a family that includes species causing widespread arthropod disease; some have been implicated in colony collapse in honey bees (*Apis mellifera*). The virus was recovered from Argentine ants from 26 of 27 sampling sites in New Zealand. It was subsequently detected in samples of the same species from invasive populations in Australia, and from Argentina in its native range. The authors hypothesize that the virus is native to Argentina and has been spread around the world by its host.

Another virus, *Deformed wing virus* (DWV), was identified in the New Zealand ant samples during screening for viruses associated with other Hymenoptera. The strain of DHW found is a major pathogen common in Hymenoptera in New Zealand, occurring in honey bees and the invasive alien common wasp, *Vespula vulgaris*. The authors suggest this indicates that pathogens are exchanged by the Hymenoptera when they interact – for example, when Argentine ants attack honey bee colonies – and that there can an interchange of native and alien pathogens.

Argentine ants have invaded every continent bar Antarctica. They were first found established in New Zealand in 1990 in Auckland, and are an increasing problem in towns and cities throughout the country. Their natural dispersal is quite slow because queens do not fly, but it is enhanced by human activities: they 'hitch a ride' in items such as potted plants, freight and refuse. Natural areas are also at risk: an infestation has been found in a marine reserve on North Island's Coromandel Peninsula.[2]

Unexplained crashes or disappearances of invasive alien ant populations have been reported from a number of countries. In New Zealand, a 2012 study[3] found populations of Argentine ant had collapsed in 60 of 150 locations surveyed, and were reduced in some of the remainder – effects apparently unrelated to pest management measures. Moreover, where colonies had collapsed, native communities were re-establishing. These authors suggested that the remarkably low genetic diversity of the Argentine ant population in New Zealand might be making it susceptible to other factors, such as pathogens.

The authors of the new study[1] say it is the first report to their knowledge of viruses in the Argentine ant. Moreover, evidence for active replication of both viruses was found in queen and worker ants, which suggests the viruses are parasitizing the ants, rather than just being vectored. LHUV-1 may therefore be implicated in the population crashes observed in Argentine ants in New Zealand. They may therefore have potential in biological control programmes.

The reverse side of the coin comes from the finding that native and alien Hymenoptera 'share' viruses, as described above. While native pathogens may inflict severe disease on evolutionarily and immunologically 'naïve' alien species and hinder their establishment, native species are potentially more at risk from the alien pathogens introduced with invasive species. The invasiveness of the exotic species means they may act as a very effective dissemination mechanism for the pathogens they carry. It also means that methods developed for using such viruses as biocontrol agents need to be carefully evaluated.

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Are Invasive Ant Supercolonies More Susceptible to Pathogens?

A paper in *Biological Invasions*[1] reports on a 10-year field study that used the invasive garden ant *Lasius neglectus* and the ectoparasitic fungus *Laboulbenia formicarum* as a model to investigate whether supercolonies of ants are more prone to the spread of pathogens than ants in discrete colonies. Supercolonies have a high density of genetically similar individuals interacting over extensive areas, so such a hypothesis makes intuitive sense – a supercolony presents a large target with high transmission rates between nests – but there is limited evidence to support it.

Lasius neglectus is native to Asia Minor and was first detected in Europe in Hungary in 1990. It has since spread through Europe, mediated by human activities, following probably several separate introductions. Although it inhabits steppe habitats in its native range, in Europe it thrives in urbanized areas, where its range now extends through Mediterranean countries to Spain, and north to Belgium, Germany and Poland. In some areas it has reached pest status with supercolonies covering several hectares. *Lasius neglectus* is one of the few ants that have become invasive in temperate latitudes.[2]

Laboulbenia formicarum has been recorded from several genera in the ant subfamily Formicinae in North America. The fungus was first detected in Europe on the native species *Lasius grandis* on Madeira in 2002. Subsequent surveys in mainland Europe discovered it on *L. neglectus* – a new association – in three of 174 introduced populations, but not from any other ant species.[3] The general mode of transmission occurs primarily through spores via direct contact, and infection increases host mortality only moderately.

In Europe, *L. neglectus* forms dense supercolonies of interconnected nests with many queens, free movement of worker ants, and sharing of territory with no intraspecific aggression. This contrasts with most native ant species, whose social structure is based on single-queen nests and high aggression against neighbouring nests. These differences are thought to contribute to invasive success of introduced ants more generally, but the 'fortress' behaviour of the native, single-queen ants may protect them from disease transmission between nests.

In a field study in northern France, the authors sampled worker ants at two *L. neglectus* supercolony sites with *Laboulbenia formicarum* infection in 2002–2007 and 2010–2014, respectively. They obtained strikingly similar results from the sites: prevalence of the fungus rose 14% annually. At the outset, a small proportion of workers were infected, but 80% were infected by the end of the study. Native species in the same subfamily were sampled in the same areas, but none was found to be infected despite close proximity and exposure to infected *Lasius neglectus*. Laboratory cross-infection studies indicated, however, that one of these, the native *Lasius niger*, could be cross-infected with the fungus from infected *L. neglectus*.

The long-term outcome of the new association cannot be predicted, and this was in any case a study to test a hypothesis. The new association between *L. neglectus* and *Laboulbenia formicarum* – species from different continents and biogeographic regions and in contact for at most 20 years – meant that there would be no evolutionary adaptations (ecological, behavioural, physiological) to hinder pathogen movement, while the benign nature of the fungal infection meant that communication between nests was not interrupted by high mortality as infection levels increased. The authors conclude, however, that the "vulnerability of the social organization of invasive ants in supercolonies points to an Achilles' heel that might be exploited in biological control using natural enemies."

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Tackling Invasive *Rubus* on the Galapagos Islands

A project involving the Galapagos National Park Directorate, CABI and the Charles Darwin Foundation is researching the potential for classical biological control of an alien *Rubus* species threatening agriculture and a unique forest ecosystem on the Galapagos Islands. *Scalesia*, a genus of Asteraceae endemic to Galapagos, includes species that that grow as trees, with the tallest reaching 20 m in height. Growing in dense stands, daisy trees are the dominant members of the islands' humid cloud forests.

Many species from the genus *Rubus* are invasive outside their native range, and one of them, *R. niveus* is an aggressive invader considered to be among the worst alien plants on the Galapagos Islands. It was introduced to Santa Cruz for agricultural purposes as recently as 1968, but has now invaded most of the wetter parts of the islands and covers more than 30,000 ha of open vegetation, shrubland and forest. It forms dense spiny thickets up to 3 m tall, turning agricultural areas into wasteland and preventing the daisy tree-dominated forest from regenerating. Control of *R. niveus* using manual labour and herbicide application is difficult, expensive, and ultimately not very successful owing to the plant's fast growth rate and large seedbank.

With funding from FEIG (Fondo para el control de las especies invasoras de Galápagos) for the first phase of the project, the scientists' aims are to pinpoint the origin of the *R. niveus* population introduced to Galapagos, survey for natural enemies in the native range, and identify priority candidates for introduction as classical biocontrol agents. Farmers, Galapagos government departments and NGOs expressed their support for the project at a stakeholders' meeting held at the Charles Darwin Research Station in July 2015.

Rubus niveus has an extensive native range in Asia – from Afghanistan through South Asia and China to Southeast Asia – where it reaches only a fraction of the height and density it achieves on the Galapagos Islands, potentially at least in part because of the impact of natural enemies. First surveys for plant material and natural enemies were conducted in three areas in India: the Kullu Valley and Shimla in the foothills of the Himalaya in Himachal Pradesh where *R. niveus* is considered to be native, and the Nilgiri Hills in Tamil Nadu in southern India which may also be a centre of diversity of the species. Surveys were also conducted in three provinces in south China: Yunnan, Guizhou and Sichuan.

The published literature suggests that *R. niveus* on the Galapagos Islands originated from India, but this needs to be verified. Genetic markers are being developed using material collected during the surveys, and *R. niveus* samples from Galapagos and other introduced populations around the world. Plants show significant variability across the native range (e.g. leaf and stem morphology). Pinpointing where the Galapagos population originated from, and targeting surveys there, should increase the chance of finding a genotype of the selected biocontrol agent that is fully compatible with the weed, and hence one that has the most impact on the weed.

Natural enemies recovered during the first surveys are being identified in China at the CABI–Ministry of Agriculture Joint Lab for Biosafety in Beijing, and in India by two Indian Council of Agricultural Research (ICAR) institutes: arthropods at the National Bureau of Agricultural Insect Resources (NBAIR) in Bengaluru [Bangalore], Karnataka, and pathogens at the National Bureau of Agriculturally Important Microorganisms (NBAIM) in Maunath Bhanjan, Uttar Pradesh. Export of promising natural enemies is hoped to start in 2016. This will allow host-specificity screening alongside research into life cycles and rearing to be conducted at CABI's quarantine facilities in the UK.

While there are no native Rosaceae on the Galapagos Islands, there are19 native species in mainland Ecuador, all of which will be included in the host-specificity screening process; one species of economic importance, cultivated for its berry juice, *Rubus glaucus* or 'mora', is a key test species. There is still a long way to go but, encouragingly, preliminary screening by CABI in China has shown that *R. niveus* from the Galapagos is susceptible to a rust pathogen collected during surveys in that country, while *R. glaucus* from Ecuador is immune. Rust species have previously been successfully used against invasive *Rubus* species in Chile and Australia. In addition to efficient dispersal abilities and damage to hosts, rusts can exhibit interspecies specificity which confers the narrow host range essential for a biocontrol agent – but this makes it all the more important to locate the origin of the genetic material on the Galapagos Islands and survey there for natural enemies.

If a suitable candidate agent is found during this first phase, additional funding will allow a rigorous 3–5 year testing programme to be undertaken, before the agent can be considered safe for release on the Galapagos Islands to control this aggressive weed.

Further Information

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Lace Bug Released against Privet in New Zealand

New Zealand became the first country to implement biological control of privet (*Ligustrum* species) with the release of 1000 privet lace bugs (*Leptoypha hospita*) by the Waikato Regional Council at two sites on North Island's Coromandel Peninsula in September 2015. The lace bugs were bred at Landcare Research's Auckland facility and approved for release in New Zealand by the Environmental Protection Agency in May. Other field releases are planned for this spring.

New Zealand has no native privet species, and two of four naturalized species are significant weeds: Chinese privet (*Ligustrum sinense*) and tree privet (*L. lucidum*). Privets are evergreen shrubs or trees. Both the weedy species, which originate from China, were introduced as ornamental and hedging plants, and were reported as naturalized in the 1950s. Reproducing from seed that is spread by birds, they have since become abundant in North Island. They also occur in warmer parts of South Island but are less of an issue. In North Island they invade native plant communities, replacing native shrubs and small trees and stopping the regeneration of native seedlings. Both species are common in urban areas and are somewhat controversially linked with allergies such as hay fever and asthma. Current control methods rely on felling and cut-stump treatment with herbicide, which is highly labour-intensive and therefore expensive.

The Landcare Research programme was able to draw on knowledge developed during an ongoing biological control programme against Chinese privet in the USA. Surveys in 2005–2006 by scientists from the US Department of Agriculture, Forest Service, Southern Research Station (Athens, Georgia) and the Invasion Ecology and Biocontrol Lab, Wuhan Botanical Garden/Institute, Chinese Academy of Sciences recovered over one hundred natural enemies on Chinese privet in China. The privet lace bug was found in abundance and its feeding resulted in a bleached appearance of leaves and premature defoliation. The results of their subsequent host-specificity tests were made available to Landcare Research scientists, who conducted additional tests on species of concern to New Zealand. The privet lace bug attacks both Chinese and tree privet, feeding on the leaves of the plants and causing defoliation when present in large numbers.

Privet belongs to the olive family, which has only one native genus in New Zealand, but several species in the Oleaceae have ornamental or economic value – in particular olive. The results of the US and New Zealand tests provided evidence that New Zealand's native plant species and olives would not be at risk. The closest relative to privet growing in New Zealand is lilac (*Syringa* spp.) – a prized ornamental that also provides nectar for butterflies. This proved not to be a primary host for the lace bug, although it might be subject to incidental spill-over feeding damage where privet lace bugs are abundant on nearby privet. No other ornamental species are were found to be at risk, and the environmental risk assessment, which includes public consultation, found no other adverse risks of releasing the lace bug.

Further Information

Landcare Research – privet application webpage. Web: www.landcareresearch.co.nz/science/portfolios/managing-invasives/weeds/biocontrol/approvals/completed/privet

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Biological Control Puts Farmers Back in Clover

Extreme measures tend to be expensive, but an economic assessment of an intensive biological control effort in 2014–2105, in which a million parasitic wasps were released against the clover root weevil (*Sitona obsoletus*) in the Southland and Otago areas of South Island, New Zealand, showed that it had a net benefit across all types of farms.[1]

Clover root weevil is a Palaearctic species that was first detected in North Island in 1996, by which time it was already widespread. It continued to spread throughout North Island, reaching South Island by 2005, and by 2015 was present throughout New Zealand. The adults feed on white clover leaves and can impede seedling establishment, but most damage is inflicted by the root-feeding larvae, which reduce nitrogen fixation and weaken or kill the plants. Maintaining pasture production has been an expensive business for farmers, involving synthetic nitrogen, additional non-susceptible forage plants and supplementary feeding.

A braconid wasp, *Microctonus aethiopoides*, was introduced to North and South Islands in 2006, and its dispersal (through natural spread and releases) has matched that of the weevil, albeit with populations lagging the weevil by about two years – during which time farmers endured severely reduced white clover production and increased production costs. In general, biological control has then been effective. In Otago and Southland during 2013 and 2014, however, damage to white clover from the newly arrived root weevil was particularly acute and prolonged. These extraordinary circumstances prompted AgResearch, Dairy NZ and Beef+Lamb NZ to implement the intensive programme of parasitoid releases during the (July–June) financial years 2013/14 and 2014/15.

A paper presented at the New Zealand Plant Protection Society's Annual Conference this August[1] evaluated the economic costs and benefits of the biological control releases in Southland in 2015, which is where and when the majority of releases were made. Results indicated positive returns in 97.5% of simulations, with benefits from biological control on dairy farms of NZ$14.78/ha/year, and on sheep and beef farms of $6.86/ha/year – a total for all farms in these regions of $7 million.

[1]Basse, B., Phillips, C.B., Hardwick, S. and Kean, J.M. (2015) Economic benefits of biological control of *Sitona obsoletus* (clover root weevil) in Southland pasture. *New Zealand Plant Protection* 68, 218–226

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Biological Control of Leafy Spurge Helps Elk

A study in 2013 has shown that biological control of leafy spurge (*Euphorbia esula*) by *Aphthona* spp. flea beetles two decades after they were released has created more favourable winter habitat for elk and other wildlife in the mountain foothills of northern Utah.[1]

The flea beetles and leafy spurge are a documented biological control success story in North America. The Utah study was conducted as a long-term evaluation in an open meadow of herbaceous vegetation, which is managed as winter range for elk and was once a dense stand of leafy spurge. Sampling plots were established in 1995, during the period when three species of *Aphthona* were being released, and data were collected on abundance of flea beetles, leafy spurge and other plants. Extensive defoliation was observed in the stand in the late 1990s. The plots were revisited in 2001, when the density of leafy spurge was found to have dropped by 88%. Visits in 2012 found even fewer stems.

In spring and summer 2013, biocontrol insects and vegetation were sampled intensively in the same plots: at its summer peak, leafy spurge density was 4% of the 1995 level and the biomass was about 10% of that in 1995. In contrast, grass and forb biomass had increased 269% and 507%, respectively, and grasses rather than leafy spurge dominated the site. Flea beetle abundance over the years followed a predictable pattern, from very low numbers in 1995, to high numbers and very visible plant damage in 2001, but then lower numbers in 2012/13 corresponding to the low prevalence of leafy spurge; nevertheless, feeding damage was visible on all sampled stems by late summer 2013. In addition, all stems were damaged (typically causing total loss of flowers) by a fourth agent, the cerambycid stem-borer *Oberea erythrocephala*, which had immigrated to the site naturally by 2008.

Although exotic grasses were the dominant species at the site in 2013, native forbs had a higher biomass than exotic forbs. Overall, native species remained a relatively minor component of the plant community, but the massive decrease in leafy spurge and its replacement by grasses and other forbs meant the site was a better foraging habitat for elk and other wildlife.

[1]Anderson, J.M., Willden, S.A., Wright, D.L. and Evans, E.W. (2015) Long term outcomes of population suppression of leafy spurge by insects in the mountain foothills of northern Utah. *American Midland Naturalist* 174, 1–13.

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Two for the Price of One

Research in progress in the British Isles suggests that recovery of populations of pine marten (*Martes martes*) can alter the balance between the invasive alien grey squirrel (*Sciurus carolinensis*) and the native red squirrel (*S. vulgaris*).[1]

The pine marten, an elusive predator in the mustelid family, was driven out of large parts of the British Isles in the 19th century through habitat loss and persecution and is now the second-rarest mammal. The grey squirrel arrived in Britain in the 1870s and Ireland in 1911. In Britain, it mostly replaced the red squirrel, partly through competitive displacement but particularly because it is an asymptomatic vector of squirrel pox virus (SQPV), which is lethal in red squirrel. In Britain, red squirrel is now largely confined to central and northern Scotland, where it is under threat, as the grey squirrel front moves north. Only isolated, highly managed populations remain in England and Wales. In Ireland, although SQPV did not arrive until 2011, red squirrel was replaced by grey squirrel in most of the eastern half of the island. The pine marten, however, has seen a reversal of fortune in the British Isles in recent decades, aided by environmental legislation, reforestation and active conservation. It has begun to recolonize its former range, and there is evidence that this is affecting red and grey squirrel populations.

Anecdotal reports from foresters and gamekeepers in the Irish Midlands suggest that red squirrels have reappeared and grey squirrel numbers have fallen in areas recolonized by pine marten. The observations were borne out by a quantitative study published in 2014 by Emma Sheehy and Colin Lawton, which found grey squirrel populations have crashed over a 9000-km^2 area and the invasion front has shifted 100 km east.[2] Sheehy has since begun a study in Scotland, where pine marten has also recolonized much of its former range, and impacts on grey squirrel have been reported where the species' distributions overlap.

The extent to which pine marten can act as an effective biological control agent of grey squirrel is not yet certain. Effects of pine marten on grey squirrel may differ between Ireland and Scotland, owing to factors such as pine marten densities and regional variability in availability of alternative marten prey. In 2015, the pine marten made news headlines when the first verified pine marten sighting in over a century was made in England, and pine martens were translocated from Scotland to Wales to bolster the small, isolated population there.[3] This raised the profile of the pine marten–squirrel research, as the public's imagination was captured by the notion that conservation of the elusive pine marten might help survival of the red squirrel.

[1]Sheehy, E. (2015) Resurgent pine martens could be good news for red squirrels.
Web: theconversation.com/resurgent-pine-martens-could-be-good-news-for-red-squirrels-46051

[2]Sheehy, E. and Lawton, C. (2014) Population crash in an invasive species following the recovery of a native predator: the case of the American grey squirrel and the European pine marten in Ireland. *Biodiversity and Conservation* 23, 753–774.

[3]Vincent Wildlife Trust.
Web: www.vwt.org.uk/

Schoolchildren and Morning Walkers Learn about Biological Control

The Indian Council of Agricultural Research's (ICAR) National Bureau of Agricultural Insect Resources (NBAIR) in Bengaluru celebrated its Foundation Day (24 September 2015) in a variety of ways. The events began the previous day, the highlight being an exclusive exhibition on insects and home-grown biocontrol technologies for schoolchildren and farmers. Over 500 eager-to-learn schoolchildren from several schools in Bengaluru thronged the campus, saw first-hand what the insect-world could offer to them, and went away completely mesmerised. Applying the 'catch 'em young' philosophy, the children were taught how important biological control is in the present scenario of environment consciousness. The 'Insectarium' was where they could see live insects and grasp what these tiny creatures are capable of. In addition to biocontrol agents, the children were exposed to several more insects that impact on human life in one way or another, including the lac insect, the cochineal, compost-producing chafer beetles, honey bees, vinegar flies, aquatic insects and pests of crops. Also, pinned specimens provided a glimpse of the diversity of insects. The 'Insect Photo Gallery' was another attraction for the children. The farmers that wholeheartedly lent their fields for biocontrol experiments and who themselves are staunch supporters of biological control were honoured. Besides recognizing meritorious staff, Dr Abraham Verghese, Director of NBAIR, unveiled photographs of Dr V.G. Prasad and Dr S.P. Singh, former Project Coordinators of the All-India Coordinated Research Project on Biological Control of Crop Pests and Weeds. There were also competitions and a cultural programme to mark the occasion.

The celebrations spilled over into the Sunday (27 September), when morning walkers and joggers as well as nature buffs from all walks of life were exposed to biological control in the iconic Cubbon Park in the heart of Bengaluru. The local Department of Horticulture facilitated this half-day programme in collaboration with NBAIR with a view to familiarizing city dwellers with pest insects and biocontrol agents. With ever-shrinking space, kitchen gardening has moved up to the terrace in this garden city. A considerable number of people are now growing their own vegetables and fruit, which they want pesticide-free. Hundreds of these organic 'farmers' benefitted from this exercise as 'seeing was believing' for them. Trichogrammatids, chrysopids, coccinellids, entomopathogenic fungi and entomopathogenic nematodes were some of the agents showcased during the occasion.

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Citizen Science Documents *Harmonia*'s Spread in Britain

A paper in *Ecological Entomology*[1] describes how *Harmonia axyridis* has invaded the whole of Britain (England, Scotland and Wales) since it was first recorded in southeast England in 2004. Its spread has been monitored since 2005 by 'The Harlequin Ladybird Survey' (www.harlequin-survey.org/), an online recording scheme and citizen science initiative.[2] From this, researchers have logged the decline of seven out of eight native species and correlated it with the spread of *H. axyridis*.

Harmonia axyridis established in Europe following its introduction by the horticultural industry as a generalist predator predominantly in glasshouse crops; in the absence of proper risk assessment it was erroneously assumed to be unlikely to overwinter in the wild in Europe. By the end of 2009 it had spread to all regions of England and Wales. It has now been found on Orkney and Shetland off the north coast of Scotland. Only adults have been recorded on these islands, however, probably imported with produce, and there is no evidence of establishment that far north in Britain. Although established further south in Scotland, *H. axyridis* is most abundant in the southern half of Britain (which is warmer and drier).

As a model species for understanding mechanisms of invasion, *H. axyridis* has spurred collaborative research worldwide. The paper reviews and summarizes research findings over the last decade in Britain, as a contribution to the global body of work. This included experimental work, field surveys, and studies based on data from the monitoring scheme. The authors underline the value of citizen science initiatives for providing large datasets for large-scale and long-term ecological research, and for alien species surveillance.

[1]Roy, H.E. and Brown, P.M.J. (2015) Ten years of invasion: *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae) in Britain. *Ecological Entomology* 40, 336–348.

[2]*Harmonia axyridis* is also present in Ireland; records are available from both the UK Ladybird Survey/Harlequin Ladybird Survey and Biodiversity Ireland (www.biodiversityireland.ie/).

BioControl First Virtual Issue

The first virtual issue of *BioControl* has been posted. These special issues will focus on cutting-edge topics by presenting key articles that have been published in the journal in recent years. The theme of the first issue is 'Predator behaviour and life-history traits important for biological control'.

Web: www.springer.com/life+sciences/entomology/journal/10526