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General News

Britain Holds Public Consultation on Japanese Knotweed Biocontrol Agent

On 23 July 2009, officials at the UK Department for Environment, Food and Rural Affairs (Defra) announced the start of a three-month public consultation seeking views on the possible release of the non-native psyllid *Aphalara itadori* to help control Japanese knotweed (*Fallopia japonica*). The consultation marks the next step in the CABI-led biological control project against this weed.

Japanese knotweed is one of the most damaging invasive species to arrive in the UK, continental Europe, the USA and Canada. It was introduced from Asia to Europe in the early to mid 19th century as an ornamental plant. In its native Japan, the plant presents little or no problems owing to the impact of natural enemies, but in its introduced range it is capable of growing 3 m in as many months. In the UK, its vigorous growth inflicts damage to buildings, paving, archaeological sites, riverways and railways in many parts of the country. It also harms biodiversity, excluding native plants through its dense growth habit.

The cost to the UK economy is also great. In 2003, the UK Government put the cost of control, if attempted countrywide, at over UK£1.5 billion. Since then, both the cost and the problem have grown. These control methods rely mainly on chemicals and have been deemed unsustainable and unsuitable for a national eradication programme. A longer-term solution to the problem was therefore required. In 2001, a consortium of partners was brought together to form a project management board, which has managed a scientific research programme examining the potential for biological control of Japanese knotweed. Organizations represented on the board, and providing the necessary funding for this work, are British Waterways, Defra, Welsh Assembly Government, Environment Agency, Network Rail and South West Regional Development Agency, all coordinated by Cornwall County Council. CABI won the tender to conduct the full programme in 2003, following a scoping study in 2000 which confirmed the potential for biological control of Japanese knotweed.

Over a period of six years, CABI considered more than 200 possible control agents, identified in collaboration with Kyushu University in Japan, during surveys of Japanese knotweed in its home range. Although most agents were rejected, host-specificity tests conducted over four years using 87 test plant species demonstrated that the psyllid *A. itadori* from Japan is highly specific to Japanese knotweed and shows good potential for its control in Great Britain. Research shows that the introduction of the psyllid will not adversely affect native biodiversity and could result in a significant reduction in environmental damage as well as in costs associated with tackling Japanese knotweed conventionally through the use of chemicals and physical removal.

If a licence is issued, it is expected that the psyllid would be released and monitored, at a small number of sites initially, in spring 2010 at the earliest, followed by wider release in England and Wales. The Food and Environment Research Agency (Fera – formerly the Central Science Laboratory) is the licensing authority for the psyllid under the Plant Health Act 1967 and, in England, for its release to the wild under the Wildlife and Countryside Act 1981. The Welsh Assembly Government's Department for Environment, Sustainability and Housing is the licensing authority for the 1981 Act in Wales. A plant health Pest Risk Assessment has been carried out in accordance with the European and Mediterranean Plant Protection Organization (EPPO) template and is the focus of the consultation.

The Wildlife and Countryside Act application has also been reviewed by the Advisory Committee on Releases to the Environment, which has supported issuing a licence, dependent on certain licensing conditions. The research has most recently been peer-reviewed by three independent expert scientists.

Speakers at the launch of the public consultation included two Cornish representatives, Counsellor Julian German, Cornwall Council's Environment Portfolio Holder, and Steve Crummay, Living Environment Manager, Cornwall Council and Chair of the Japanese Knotweed Research Project Board. They were followed by Trevor Renals, Invasive Species Advisor to the Environment Agency and co-instigator of the Cornwall Knotweed Forum in 1997, and Dick Shaw, lead scientist for the CABI Japanese knotweed project. There then followed presentations from Defra and Fera, who clarified the regulatory picture for authorization of any release.

Further information about the project can be found at: www.cabi.org/japaneseknotweedalliance

In addition, the information pack produced for the public consultation is worth a look, especially for any country new to classical biological control and considering how to present the topic to its citizens:
www.cabi.org/files/jkeventpack.pdf

The fact that this would be the first time a weed biological control agent had been introduced to Europe, let alone the UK, means the project has to deal with scepticism – something at which Europeans excel. The pack begins by summarizing the physical and economic impact of Japanese knotweed on biodiversity, flooding and water quality, infrastructure and development, and safety and in social and human terms. It explains why the psyllid could help provide a solution, describing its life cycle and the damage it causes, then explains the host-specificity testing pro-

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cedure, and ends by explaining what impact the psyllid is hoped to have, underlining that it is not expected to provide a quick or complete solution. Anticipating that the public's fears about non-target impacts may not have been allayed by the above description of the host-testing process (not least because it culminated in the scientists being assured of their proposed agent's safety), the pack lists eight of the other 200+ agents which were studied in more detail over the six years of the project and explains why they were rejected – and in some cases saying that this was a disappointment but unavoidable on safety grounds. It emphasizes that the most important aspect of a biological control programme is selecting the best agent for the job, and that safety is an absolute priority. Next, the pack explains how biocontrol scientists decide which plants to test – and how this was done for Japanese knotweed – and why testing just this selection of species allows reliable decisions to be made about the host specificity and safety of the proposed agent. Finally (before the traditional 'FAQs'), it profiles a selection of biological control successes against insect and weed targets in the UK and around the world that CABI has been involved in.

This is a significant step for a European country and, if the psyllid biocontrol agent is released, could pave the way for wider use of this tried and tested approach to weed management.

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Leaf Beetles Lasso Tamarisk without Hurting the Relatives in Texas and the Southwestern USA

Ranchers and natural resource managers in Texas, the southwestern USA and Mexico have long been in a tense standoff with exotic tamarisk (*Tamarix* spp.), also known as saltcedar in the USA and as *pino salado* or *cedro salado* in Mexico. In 2001, leaf beetles in the genus *Diorhabda* were released in North America for biological control. Now, new insights gained from successful field releases, and new research results on host specificity, agent taxonomy, ecoclimatic modelling, and release methods show that the beetles are well on their way to winning this Wild West showdown.

Water resources essential for agriculture and a growing human population, and stressed native riparian ecosystems in the arid southwestern USA, have been threatened for decades by exotic tamarisks. Ten species of *Tamarix* were introduced to North America in the 1800s for erosion control, and for use as windbreaks, fences and ornamentals. Five invasive species, known commonly as saltcedars (*Tamarix ramosissima*, *T. chinensis*, *T. canariensis*, *T. gallica* and *T. parviflora*) and various hybrids have invaded a range extending from the US–Canadian border southward to central Mexico, and from the central Great Plains westward to coastal California. Saltcedars infest at least one million hectares of arid riparian and rangeland habitat in North America, withdrawing water from rivers and reservoirs, salinizing soils, altering flood and fire regimes along rivers, and displacing native riparian ecosystems. Chemical and mechanical control methods are widely used but are expensive, pose risks to native plants and wildlife, and are not feasible for the largest invasions of tamarisk, such as the populations occupying hundreds of kilometres along rivers and reservoirs in the Rio Grande Basin of Texas, New Mexico and Mexico, and others covering thousands of hectares of rangeland in the Great Basin of eastern California, Nevada, Utah and the Lower Colorado of Arizona and southern California.

Over 300 insects feed on *Tamarix* spp. across their vast native range, the main portion of which extends from the western Mediterranean to central China[1]. After extensive risk assessments that began in 1986[1], tamarisk leaf beetles (*Diorhabda* spp.) were selected as the top priority natural enemy for introduction by the US Department of Agriculture – Agricultural Research Service (USDA-ARS) scientists Jack DeLoach (Temple, Texas) and Robert Pemberton (Ft. Lauderdale, Florida), in consultation with overseas cooperators, Ivan Mityaev and Roman Jashenko in Kazakhstan, and Ren Wang, Quing Guang Lu and Baoping Li in China. The beetle (then known as *Diorhabda elongata deserticola*) was approved for quarantine importation by the USDA-Animal and Plant Health Inspection Service (APHIS) in March 1992[1]. Host-range testing initiated by ARS in Temple, Texas, and after 1998 also in Albany, California[2,3,4], resulted in approval of the beetle by USDA-APHIS for field release in May 2001. Adult tamarisk beetles deposit eggs in masses attached to foliage or bark. Larvae feed on foliage for about three weeks and then pupate on the soil surface beneath the tree. Two (in Nevada) to 4–5 generations (in Texas) are completed annually and adults enter reproductive diapause in the fall and overwinter beneath debris on the soil surface or in clumps of grass[5].

A *Diorhabda* population now known as the northern tamarisk beetle, *D. carinulata*, from Fukang, China and Chilik, Kazakhstan, was the first to be released, in six western states[2]. By 2007, these beetles had defoliated an estimated 50,000 ha of saltcedar in Lovelock and Schurz, Nevada, and additional areas in western Utah (near Delta), Pueblo, Colorado and Lovell, Wyoming[6]. Beetles were released at a redistribution site near Moab, Utah in August 2004. By July 2009, they had dispersed naturally along 750 km of the Colorado, Green and San Juan rivers in Utah and the Delores River in western Colorado, defoliating nearly 100% of the saltcedars. Willows and other native plants revegetated naturally and abundantly at several sites within two years after defoliation. Repeated defoliation by larvae depletes carbohydrate reserves in the root crown and is followed by a reduction in spring regrowth and flower production. After four years of defoliation, extensive die back occurs and trees begin to die[7].

The Fukang/Chilik tamarisk beetles did not establish below the 37th parallel North latitude in Texas and California due to daylength constraints that led to early diapause induction[8]. Tamarisk beetles were therefore collected from sites at lower latitudes in the native range. Ray Carruthers (USDA-ARS, Albany, California) and Javid Kashefi collected *D. elongata* in Crete, Greece. Kashefi, Rouhollah Sobhian and Alan Kirk (USDA-ARS European Biological Control Laboratory [EBCL], Montferrier-sur-Lez, France/ Thessaloniki, Greece) collected in Uzbekistan (*D. carinata*), and Tunisia (*D. sublineata*)[9]. The biological safety of these beetles (under their previous shared name, *D. elongata*) was verified in a variety of laboratory and outdoor caged tests at Temple and Albany[10].

Two critical issues limiting the ability of scientists and resource managers to make releases of tamarisk beetles have been addressed by recent research. The first issue was ecoclimatic suitability of the tamarisk beetles for the numerous ecoregions of the southwestern USA and northern Mexico, which vary substantially in daylength, precipitation, temperature regimes, and in dominant flora other than tamarisk[9]. The tamarisk beetles, previously considered as populations or 'ecotypes' of one species (*D. elongata*) were redescribed as five species[9], including the four noted above that have been introduced to North America. Taxonomic research also involved the development of a habitat-suitability index (HSI) model, using hundreds of climatic and museum collection data points from the native range, to determine the ecological regions in which each beetle species is most likely to establish on invasive tamarisk in North America. For example, the model predicts that the subtropical tamarisk beetle from Tunisia is most suited for riparian areas of south Texas and northeastern Mexico; the Mediterranean tamarisk beetle from Crete for central Texas and the central San Joaquin Valley of California; and the greater tamarisk beetle from Uzbekistan for northern Texas, and New Mexico[9]. Field studies are underway in north and southwestern Texas to evaluate these model predictions.

The second major issue addressed by recent research involves the ability of tamarisk beetles to feed and reproduce in the open field on two types of plants other than saltcedars. The first is athel (*Tamarix aphylla*), known as *pinabete* in Mexico. Athel is a large (up to 20-m-tall), evergreen tree whose native range extends from North Africa through the Middle East to Pakistan. This exotic tree is used for shade and as a windbreak near homes and on rangelands in Mexico and to a lesser extent in the southwestern USA, and is also used in beekeeping and for firewood. Athel is itself invasive in locations in California, Arizona and Texas in the USA and in the states of Baja California del Norte, Sinaloa and Coahuila in Mexico, as well as in Australia, but because of its occasional beneficial use, it is considered to be a non-target plant in biocontrol of saltcedar. Laboratory and field-cage tests[3,4,10] had demonstrated that the four introduced *Diorhabda* spp. beetles, if given no choice, can complete their development on athel, and can reproduce almost as well when reared on athel as when reared on saltcedars, although in choice tests the beetles lay only about 40% as many eggs on athel as on saltcedars. The other potential non-target plants are six native members of the genus *Frankenia* (in the same order as *Tamarix,* Frankeniaceae, order Tamaricales), which grow as small shrubs and herbs and are the closest native relatives of *Tamarix* in North America. Alkali heath (*Frankenia salina*) is widespread as one coastal and one inland form in California and western coastal Mexico, while the other five species are endemic and sparsely distributed in deserts in the southwestern USA and northern Mexico. Tamarisk beetle larvae can survive to adulthood on *Frankenia* spp. (0–60% as many as on tamarisk) when given no choice. However, only slight feeding damage and egg laying occur on *Frankenia* spp. (0–5% of saltcedar) in choice tests in Texas[3,4,10] with higher levels of egg laying and damage on *F. salina* in tests by John Herr at USDA-ARS, Albany, California[11]. Recently-published work, based on 2005–2007 studies[12], found that in open-field, uncaged tests, the Crete beetles lay 70–87% of their total eggs on saltcedar and 13–29% on athel, with virtually no alighting, feeding or egg laying on *Frankenia* spp. During these tests, *D. elongata* tamarisk beetles established a low-density population on saltcedar tamarisk at one site in south Texas, and a large, defoliating population at the Big Spring, Texas. These results represent the first open-field comparisons of saltcedar and athel in North America and the first open-field tests of *Frankenia* spp. in Texas[12].

In unpublished, recent, follow-up tests in south Texas, Patrick Moran demonstrated that *D. elongata* and *D. sublineata* beetles disappeared rapidly when released on mature athel trees where no saltcedar is available, likely because of reduced attraction to athel for ovipositing tamarisk beetles. These important results, in combination with prior published studies, suggest that athel trees being used for beneficial purposes, such as to provide shade, are not in danger from biological control of saltcedars.

DeLoach, Allen Knutson and colleagues released *D. elongata* from Crete in 2004, and they established a robust population at a site along Beals Creek near Big Spring, in west-central Texas[12,13]. After 2006, beetle dispersal and saltcedar defoliation began increasing rapidly, as the beetles formed large aggregative 'swarms' and dispersed long distances (a few 100 m to 8 km or more), establishing satellite colonies. This 'swarming' behaviour appears to be a predator avoidance strategy that effectively avoided or overwhelmed ants and other predators. By July 2009, the beetles had defoliated 90–98% of the trees over more than 350 ha of saltcedar along a 25-km reach of Beals Creek; 25% of the trees that were defoliated twice annually for three or more years were killed. The local pasture grasses revegetated naturally and abundantly within one or two years after defoliation of the saltcedar canopy.

Protocols for releasing beetles and maximizing establishment were developed by Knutson and DeLoach, and include the use of field cages to propagate beetles on tamarisks in the field; pruning of tamarisks in and around the cage to generate fresh foliage; releasing during the spring; and controlling predatory ants in and around field cages. The work at the Big Spring, Texas site has led to new protocols for monitoring *Diorhabda* spp. beetles and recovery of native plants and wildlife. These improved procedures have been essential for the implementation of tamarisk biological control at over 40 sites in Texas in 2008–2009. Beetles have now established populations and are defoliating tamarisk along the Upper Colorado and Pecos rivers in west Texas, and are poised to establish at several other sites.

Communication with stakeholders and the public has been an essential component of the biological control programme for tamarisk. Field days have been held annually at the Big Spring, Texas site since 2005 to update natural resource managers and landowners on progress and to promote redistribution of the *Diorhabda* beetles to new sites. Numerous newspaper and magazine articles have been published. In March and June 2007, bi-national meetings were held in El Paso, Texas, and Juarez, Mexico, with Mexican wildlife and resource agencies to discuss their concerns about athel and *Frankenia* spp., as well as hybridization and habitat expansion by the beetles. From 2007 to 2009, *D. elongata* and *D. sublineata* beetles were released at 16 sites on the US side of the Rio Grande, from Big Bend National Park to Candelaria. Monitoring of control and of beetle impact on native plant and wildlife communities are ongoing. The dialogue with Mexico (including several presentations at Mexican scientific meetings since 2003) has been aided by the recent research results.

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Clinging On: A Review on the Biological Control of Cat's Claw Creeper

Macfadyena unguis-cati is a woody, frost-tolerant perennial vine with a native range which spans over 6000 km of central and tropical South America. Its distinctive leaves consist of two leaflets and a terminal three-forked tendril from which the vine draws its name. A tiny hardened hook on each fork can attach to most surfaces and thus enable the plant to 'climb' up walls, tree trunks and other vegetation[1]. Due to this climbing habit as well as its showy yellow flowers, cat's claw creeper has been widely distributed around the world as an ornamental and has been used as a fast-growing creeper for hedges and walls. Unfortunately, the vine has since become invasive in a number of regions in southern Africa, Australia, New Zealand, India, Mauritius, China, New Caledonia and the USA, including Hawaii. Within these countries, cat's claw creeper has become a significant invader of cultivated orchards and plantations, riparian corridors, natural forest remnants and disturbed areas such as roadsides and urban spaces. Vigorous growth of the weed facilitates dense infestations which sprawl over other vegetation and, through a combination of both shading and weight, can kill even the largest canopy trees. In the absence of climbing support, individual stems grow along the ground resulting in a thick carpet which precludes the growth and seed germination of understorey vegetation. In this way, cat's claw creeper has become a significant threat to biodiversity throughout its introduced range.

The management of cat's claw creeper is extremely difficult. Mechanical control is hampered by the weed's extensive vegetative growth, profuse seed production, and the presence of subterranean root tubers. Individual stems growing along the ground readily develop roots wherever nodes touch the ground. Whether produced at stem nodes or along lateral roots, these tubers can develop into new plants if separated from the parent plant. The presence of tubers makes infestations extremely resilient as they will readily resprout if aerial parts are damaged or removed, for example via mechanical weeding or fire. The ability to resprout also enables the plant to withstand adverse conditions such as heavy frost or drought. Chemical control options are thus similarly unsuccessful as they predominantly target only above-ground growth leaving the tuber bank relatively untouched. Chemical control and in particular the use of broadleaf herbicides is further complicated by the potential for non-target effects to the sensitive or economically important ecosystems that the weed normally invades. Due to these constraints as well as the prohibitive costs associated with manual and chemical controls, weed management practitioners have prioritized biological control as the only practical and long-term solution to cat's claw creeper infestations.

Initiation of Biological Control

Within South Africa, cat's claw creeper is still considered to be in the early stages of invasion as the weed's realized distribution is limited relative to its potential range as predicted by the plant's climatic requirements[2]. Although very dense in a number of centres in the warmer temperate regions of the country, infestations are still relatively isolated when compared with some of the country's other invaders. Coastal subtropical regions of South Africa which are predicted to be most suitable for the vine's growth remain, as yet, largely free from invasion. Nevertheless, the potential for further spread is high given that the weed is still present in gardens throughout the country and that seeds are readily dispersed by wind and water. With this in mind, a biological control programme was initiated in 1996 by the South African Plant Protection Research Institute which resulted in the release of the first natural enemy against cat's claw creeper three years later, namely the golden-spotted tortoise beetle *Charidotis auroguttata*[3]. This chrysomelid beetle exhibited good adult longevity and fecundity and was thus capable of high rates of population increase enabling multiple generations per year under quarantine conditions. Both adult and larval feeding was equally promising producing numerous 'windows' in the leaves which significantly reduce the amount of area available for photosynthesis. At high population densities, feeding damage can cause premature leaf abscission and the die-back of shoot tips.

In contrast to South Africa, cat's claw creeper has become naturalized over a far greater area in Australia and has become a major environmental weed throughout the continent's subtropical east coast. Confronted with the problems caused by the vine and buoyed by the anticipated efficacy and perceived specificity of *C. auroguttata*, the beetle was imported into Australian quarantine at the Alan Fletcher Research Station in Queensland in 2001. Host-specificity testing, however, revealed that the beetle was prone to 'spill over' feeding on the native plant *Myoporum boninense* ssp. *australe*. Despite the fact that the beetle was not able to sustain a viable population on this species, *C. auroguttata* was not approved for release due to the perceived risk to non-target species[4].

Initial establishment of *C. auroguttata* in South Africa was slow and the beetle failed to survive at a number of localities despite repeated releases. Nevertheless, it has become established at a few sites around the country and has managed to persist at these up till now. Although feeding damage is both widespread and abundant at these sites, population build-up of the insect is insufficient to suppress the weed's growth or spread. The lack of establishment, minimal population build-up and lack of dispersal of *C. auroguttata* could be attributed to a number of factors. Climatic mismatching was originally suspected but given the abundance of the species throughout its native range, which encompasses a variety of climatic regions within Venezuela, Brazil and Argentina, this seems unlikely. This conclusion is further supported by climatic modelling[2] and thermal tolerance work currently being done which suggests that the beetle is relatively cold tolerant. *Charidotis auroguttata* may also be prone to ant and spider predation as well as parasitism from parasitoid complexes of local South African Chrysomelidae. Host-range extension by native parasitoids has been recorded under quarantine conditions on two chrysomelid species introduced for the control of *Solanum elaeagnifolium*, namely *Gratiana pallidula* and *G. lutescens*, and in field situations on *G. spadicea*, a natural enemy introduced for the control of *Solanum sisymbriifolium*. Further studies are underway to better understand the factors limiting the efficacy of this seemingly promising agent.

Sourcing Additional Natural Enemies

Prompted by the lack of success of *C. auroguttata*, additional natural enemies were sought. Climate matching and plant genotypic studies directed surveys to areas around the southern parts of the native distribution of cat's claw creeper, in particular Paraguay, the southern reaches of Brazil and northeastern Argentina. Genotypic studies suggest that the plant haplotype present in these regions closely matches what is present in both South Africa and Australia[5]. Natural enemies collected from these regions are therefore anticipated to be most desirable in terms of their thermal tolerance and should be best suited to the particular invasive haplotypes present in South Africa and Australia. Surveys in 2002 and again in 2009 yielded several insect species, including two tingids, *Carvalhotingis visenda* and *C. hollandi*, a leaf-tying pyralid moth *Hypochosmia pyrochroma*, a leaf-mining buprestid beetle *Hylaeogena jureceki* and a seed-feeding curculionid weevil *Apteromechus notatus*, which were imported into quarantine in South Africa. With the exception of *A. notatus*, the above species have been shown to be suitably host specific and trial releases of *C. visenda*, *C. hollandi* and *H. jureceki* are currently underway in South Africa[6]. The application for release of *Hypochosmia pyrochroma* in South Africa is currently under review and the specificity of *A. notatus* is still under investigation in quarantine. Subsequent to the host-specificity work in South Africa, *C. visenda* and *H. pyrochroma* were prioritized as potential natural enemies of cat's claw creeper in Australia and were imported for testing in 2004 and 2005 respectively. Both species were found to be highly specific and approved for field release[7,8].

Simulated herbivory experiments have shown that defoliation of cat's claw creeper has the potential to significantly reduce the plant's productivity[9]. Repeated and severe defoliation was found to reduce the climbing habit of the plant and reduce the rate of tuber biomass accumulation. The above natural enemies have various modes of attack but with the exception of *A. notatus*, all are foliar feeders. Both *C. visenda* and *C. hollandi* feed gregariously by removing chlorophyll from the leaves of the vine. The larvae of *Hylaeogena jureceki* produce extensive mines beneath the leaf epidermis and eventually pupate within the leaf itself forming small disc-shaped structures. These mines are most often restricted to the larger more mature leaves whereas adult feeding is normally concentrated around younger growing points where leaves will often become skeletonized. The larvae of *Hypochosmia pyrochroma* are voracious feeders and will often consume large proportions of leaf tissue producing characteristic see-through windows and in some cases leaf skeletonization. Similarly to *Charidotis auroguttata*, feeding from the above species within quarantine significantly reduces the amount of leaf area available for photosynthesis, and at high population densities promotes premature leaf abscission and eventual shoot tip die-back. Pre-release efficacy assessments of the tingids suggest that a single generation has the potential to significantly reduce chlorophyll content, resulting in reduced plant height and leaf biomass. However, the effect of this short-term damage was restricted to the aerial parts of the plant and had no effect on below-ground biomass[10]. Whether field populations of these natural enemies can attain densities able to achieve the sustained level of defoliation synonymous with the simulated herbivory studies remains to be seen.

Future Direction

Field releases of *Carvalhotingis visenda* and *Hylaeogena jureceki* in South Africa, and *C. visenda* and *Hypochosmia pyrochroma* in Australia, have thus far yielded positive results. In South Africa, *C. visenda* was actively released in 2008 and has since become established at a number of climatically distinct sites where it is spreading well. Intense localized feeding indicated by severe leaf chlorosis has been recorded around the release points and random stem sampling indicates significant increases in feeding relative to initial evaluations done six months previously. Simultaneous releases of *Hylaeogena jureceki* at separate sites have also been promising in that the beetles have become widely dispersed, in one instance damaging leaves almost one and a half kilometres from the release point. This damage is, however, of a low intensity and, as yet, no measurable impact on plant growth or biomass has been recorded. Although large population numbers of both species were evident by the end of summer, it is still unclear how they will perform through winter, especially in the high-altitude interior of the country where frost is common and minimum temperatures regularly approach zero.

In contrast, *C. visenda* has been actively released in Australia in collaboration with local landcare and community groups in both Queensland and New South Wales since May 2007. Field establishment of the tingid was evident in all the release sites, covering both riparian and non-riparian areas, as predicted by the climate matching model[5]. In the field, *C. visenda* was observed throughout the year, but its population levels declined during summer months. Thermal tolerance studies suggest that *C. visenda* can complete three to eight generations in a year in Australia, with more generations in Queensland than in New South Wales[11]. So far, *C. visenda* appears to spread slowly in the field. To increase the virulence of the existing laboratory culture, a fresh colony of *C. visenda* was imported from Paraguay and mixed with the existing colony in Australia, and progeny from this mixed culture are now being used in field releases. Field studies on quantifying the impact of *C. visenda* are in progress.

Releases of *Hypochosmia pyrochroma* in Australia commenced in December 2007, with field releases restricted from spring to mid-autumn. As the rearing process is more labour intensive than for the tingids, only limited numbers of adult moths were field released initially. A method for laboratory rearing of the moth using cut foliage in temperature-controlled rearing cages was standardized, and as a result, larvae and adults are now being field released in large numbers. So far there is no evidence of large-scale field establishment of *H. pyrochroma* in Australia, although it is too early to ascertain its field establishment status. Field releases are due to continue for one more year. To reduce the bottleneck due to inbreeding, recently collected *H. pyrochroma* from Paraguay will be imported and mixed with the existing laboratory colony. Attempts to train local landcare and community groups in rearing and releasing of *H. pyrochroma* are in progress.

Currently, only the tingid (*C. visenda*) is known to be established in Australia, but its population levels remain low. As cat's claw creeper has an extensive network of subterranean root tubers, intense and sustained herbivore pressure is required to reduce this reserve. Hence, additional specialist insect herbivores need to be introduced to enhance and sustain this herbivore pressure. In view of the susceptibility of cat's claw creeper to leaf herbivory, and the recent successful field establishment in South Africa, the leaf-mining jewel beetle (*Hylaeogena jureceki*) has been prioritized.

Recent studies in Australia have suggested that new vine recruitment around established cat's claw creeper infestations is primarily from seeds and not through vegetative growth as previously thought[12]. This work highlights the need for specialist flower- or seed-feeding insects such as *A. notatus* in order to curb future spread of the weed. In its native range, *A. notatus* has been observed in large numbers and is able to destroy up to 80% of the seeds found within developing pods, significantly reducing seed rain. Adult weevils are long lived and are thought to lay eggs on green or immature pods. Thereafter hatching larvae will burrow into the pod and feed on numerous seeds before pupating. After overwintering as either pupae or newly eclosed adults within the pod itself, the next generation of adults emerge in spring in order to coincide with flowering and early pod production. This life history, however, presents a significant challenge to the rearing and specificity testing of the weevil in quarantine. Future efforts will thus attempt to stimulate sexual reproduction in potted cat's claw creeper plants in order for the development and culturing of this species to proceed.

In summary, it is hoped that biological control will address both the negative aspects of already established infestations through the use of leaf herbivores, and the future spread of cat's claw creeper with the use of specialist seed feeders.

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Perseverance Pays: Crambid Moth Establishes on Old World Climbing Fern

An article in the December 2008 issue of *BNI* looked at a paper in *Biological Control*[1] which had discussed why two crambid moth agents had been prioritized for introduction against Old World climbing fern (*Lygodium microphyllum*) in Florida, USA. Consistent with the known paucity of the natural enemy fauna of ferns worldwide, a biological control programme against *L. microphyllum* based at the USDA-ARS (US Department of Agriculture – Agricultural Research Service) Invasive Plant Research Laboratory (IPRL) in Fort Lauderdale, Florida had uncovered few potential biocontrol agents. The paper explained why they went ahead with releases of the first agent (the crambid leaf-feeder *Austromusotima camptozonale*; formerly the pyralid *Cataclysta camptozonale*), even though it had less than ideal characteristics, and Pyralidae (*sensu lato*) historically exhibit lower rates of establishment than other major taxa of biocontrol agent. Concerns seemed realized when it failed to establish after a total of some 10,500 adults and 30,000 larvae were released between 2004 and 2007.

Despite this, the authors argued that it was still worth trying the second crambid. The *BNI* article [*BNI* 29(4), pp. 56N–58N (December 2008), 'Climbing fern presents few biocontrol options.'] ended by summarizing the authors' view that "Lepidopteran agents can and do establish." Less than a year later, a paper recently published in *Biocontrol Science & Technology*[2] indicates their faith was justified.

In stark contrast to the experience with *A. camptozonale*, releases of just over 31,000 *Neomusotima conspurcatalis* across three locations in Florida in January–June 2008 led to not only establishment but rapid population growth: ten months after releases began, combined populations of the three sites were estimated at 11.7 million larvae, and these had defoliated more than 14,000 m^2 of climbing fern infestations. Based on their experiences with the first agent, releases of *N. conspurcatalis* were initially conducted at fewer sites, enabling substantially more individuals to be put out at a given time, with follow-up releases over subsequent weeks and months. However it should be noted that *N. conspurcatalis* successfully established at one site following the release of only 1000 adults, so it is also possible that the observed differences in establishment success between the two agents may be due to inherent differences between the two species, such as the higher reproductive capacity of *N. conspurcatalis*.

Neomusotima conspurcatalis was first found feeding on Old World climbing fern in Hong Kong in 1997 but was subsequently found elsewhere in the plant's native range in China, Southeast Asia and northern Australia. The cultures used to rear insects for release were established from material collected in Australia. The moth's larvae skeletonize the leaves, with older larvae also consuming them completely. Large moth populations cause pronounced defoliation and browning of entire plants. It is estimated there will be 10–12 generations per year of the multivoltine moth in Florida.

Monitoring at the first site, which began after 1000 adults were released in January and continued regularly to July, found low numbers of *N. conspurcatalis* adults or larvae associated with feeding damage up to 25 m from the release sites; evidence that the moth was reproducing. At the second and third release sites, where multiple releases of several thousand larvae were made between March and July, the early results were even more encouraging. Different life stages were evident in the first few months and by August populations had increased and were causing localized defoliation and browning of *L. microphyllum* near the release sites.

Revisiting the first site in October, and the other two sites in November, researchers found substantial evidence of larval feeding damage around the release sites, with plants defoliated and brown; large larval populations were seen at sites 2 and 3. Large numbers of adults were also seen, and at site 1 these flew up in clouds as the researchers walked through the site.

Neomusotima conspurcatalis is thus well-established and has caused substantial damage at release sites. Observations indicate that the zone of defoliation is spreading out from the release sites as female moths seek new sites for oviposition. Defoliated zones are surrounded by zones of actively feeding cohorts of larvae.

Although it is too early to predict the long-term impact of *N. conspurcatalis*, these early results provide a ray of hope after a gloomy start to the release phase of the biological control programme against Old World climbing fern.

The very different outcomes of releasing the two crambid species in Florida suggest that, although generalizations about the success of establishing various insect groups can be made, species should be judged on their individual traits and suitability for the proposed place of introduction. Although optimism understandably influences decisions on whether or not to release an agent, it seems that for the time being, field release programmes will remain the only sure way to determine which agents have the ability to establish self-sustaining populations in the field.

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Getting to Grips with Giant Reed in the Rio Grande Basin

Everything is bigger in Texas, and when it comes to the invasive plant giant reed (*Arundo donax*), that means very big indeed. In Texas and the southwestern USA – as well as across the border in Mexico – it can reach some 30 feet (ca. 10 m) in height, grows at rates of 3–7 inches (ca. 8–13 cm) per day and forms dense thickets in riparian systems and irrigation canals. Competing successfully for the scarce water resources of this arid region, giant reed crowds out native vegetation and can displace entire riparian forests including birds and other animal wildlife. The thickets choke stream channels, destabilize riverbanks, interfere with flood control measures, and increase fire risk. Giant reed's impact is particularly severe along the Rio Grande in Texas, while south of the border its impact on Mexican biodiversity is a serious concern and it has caused the extinction of a fish near Monterey.

Mechanical control is ineffective because plants regrow from stem and rhizome fragments, and burning is not a solution because giant reed resprouts more quickly than native species after fire. Although chemical control with herbicides can be effective, their use is feasible only over limited areas, and not for extensive infestations like those throughout the Rio Grande Basin.

Giant reed is native to Spain but is now an invasive weed in many countries around the world, and is common throughout the New World. Research by the University of California and Texas A&M University along with action groups such as Team Arundo del Norte have done a good deal to unravel the biology and genetics of this invasive species in its native Mediterranean and North American ranges. A USDA-ARS (US Department of Agriculture – Agricultural Research Service) classical biological control project, primarily focused on Texas and Mexico, has recently introduced the first classical biological control agent against giant reed. The project, led by scientists from the Beneficial Insects Research Unit (BIRU) in Weslaco, Texas, includes the ARS European Biological Control Laboratory (EBCL) in Montpellier, France, the ARS Exotic and Invasive Weed Research Unit (EIWR) in Davis, California, USDA-APHIS, Texas A&M University, Universidad de Alicante, and Instituto Mexicano de Tecnología del Aquas (IMTA).

Effective control of giant reed could bring direct savings to the USA alone of up to US$30 million annually through water conservation and reduced control costs, while indirect economic savings would accrue through reduced expenditure for riparian areas and irrigation and road repairs, and enhanced riparian habitats.

Giant reed was introduced by Spanish colonists in the 15th century. EBCL scientists conducted multiple surveys across the native range, focusing on the Mediterranean region and Spain, the origin of the invasive genotypes. These surveys confirmed that giant reed is attacked by a suite of natural enemies in its native range. Subsequent biological and host-specificity studies by BIRU scientists evaluated four insect species from Spain as potential biocontrol agents. The insects were identified by INRA (Institut Scientifique de Recherche Agronomique) and ENSA (Ecole Nationale Supérieure d'Agronomie) scientists in Montpellier.

Permission to release the first of these, the eurytomid gall wasp *Tetramesa romana*, has been given by the USDA-ARS Animal and Plant Health Inspection Service (APHIS). This biocontrol agent attacks the stem, which weakens the plant, reduces its overall height, and causes it to form galls and put out side shoots. First releases were made along the Rio Grande in Texas in March 2009 from cultures established using insects imported from the Barcelona and Granada regions of Spain. While initial monitoring takes place, releases are being confined to stands along the Rio Grande. Releases in California and Arizona are planned for the future, and this species has also been released in Mexico. In Mexico, researchers at IMTA in Cuernavaca will rear *T. romana* for release on the Mexican side of the Rio Grande and other heavily impacted areas such as the Morelos valley.

While the release of the first agent is a milestone, a second agent whose release may be approved later this year is creating even more interest. The *Arundo* scale, *Rhizaspidiotus donacis,* attacks the rhizome. An agent that has a debilitating impact on the rhizome could have a large impact on the plant's growth and spread. The scale is also very fecund, each female producing 100–200 offspring.

Two other species are still undergoing testing: the *Arundo* fly, *Cryptonerva* sp., which feeds on the inside of new shoots, and a leaf sheath miner, *Lasioptera donacis*, which destroys leaves. Thus the four agents would each attack a different part of the plant.

Main source: Anon (2009) Biocontrol battle begins against giant reed (*Arundo*). *Agricultural Research* (July 2009), pp. 12–13. USDA-ARS.
Web: www.ars.usda.gov/is/AR/archive/jul09/

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How to Spend Wisely on Weed Biocontrol

Throwing money at biological control of weeds is not a luxury any country can afford. With many weeds to control, the trick is to spend the available funds in the optimum way. But how do you know what that is? The Australian Government has recently funded a study by New Zealand's Landcare Research to develop a framework for prioritizing which weeds are most promising targets for biological control.

They began by looking at ranking processes used in countries with a strong track record in weed biocontrol, but found they have a common limitation in relying too heavily on subjective judgements without adequate supporting justification. Next they looked at published papers that related biocontrol success to plant traits – and then brainstormed. They identified three factors that need to be taken into account:

- *The importance of the weed target*: i.e. how invasive it is, its impacts, how fast it is spreading, how much land is at risk of invasion, and whether there are other effective control methods. This information was already available for more than 70 weeds in Australia, because they had been assigned scores for just such attributes under the Weeds of National Significance (WoNS) ranking scheme, so the project team could concentrate on the other two factors.
- *The effort required to undertake the project*. This is affected by whether prospective biocontrol agents are already well known, the native range is accessible, and there are likely to be conflicts of interest ("very difficult and expensive projects are more likely to fall by the wayside" – sad but true).
- *The likely impact or likelihood of success of biological control*. The best predictor of this currently is what has happened elsewhere – although this does not help with novel targets. The team thus collated from the literature hypotheses that have been proposed as to how various plant traits affect the likelihood of success. They then looked at published information on the success of completed biocontrol programmes (limiting themselves to the USA and South Africa) to see whether there was evidence to back up the hypotheses. Data on impact that had been collected in various ways was converted into an 'impact index', which was devised by Quentin Paynter, who led the project, and was defined as "the proportional reduction in weed density (e.g. percentage cover; stems/m^2; weed biomass) due to biocontrol." The impact indices were then correlated with the range of factors that have been proposed as determinants of biocontrol success to identify the important ones. It was not possible, within the tight timeframe of the project, to acquire sufficient information to assess a number of hypotheses, including the importance of host plant quality, genetic variability and susceptibility to secondary infection, and the team emphasize that more research is needed on the significance of these. Their analysis did reveal, however, that biocontrol impacts have on average been greater on (a) biennial and perennial rather than annual weeds, (b) plants capable of vegetative reproduction rather than those relying solely on seeds or spores, (c) wetland and aquatic rather than terrestrial weeds, and (d) plants not reported to be weedy in the native range rather than those that are.

Having sorted out these factors, the team developed a prototype scoring framework, and tested it with examples of South African and US biocontrol agents. They found good correlation between the likely impact predicted by running the agents through the framework and the impact indices calculated earlier (see above). The preliminary framework was presented at a workshop in the Australian capital, Canberra, and the scoring system was refined, based on feedback they received. They took the 112 Australian weeds nominated as biocontrol targets, excluded species for which biocontrol programmes were considered completed, and prepared a prioritized list of the remaining 75.

While they are confident the framework is robust and useful, they see room for improvement. Paynter says that it is useful for identifying likely 'winners' and most difficult targets, but there are a good many weeds with intermediate scores where predicting success and failure is something of a lottery. He points out that the analysis explains only about half the variation in the success of past weed biological control programmes, and that if they could identify more factors affecting success this would allow the scoring system to be modified with a knock-on effect on the predictive power of the framework. He also believes that methods for ranking weed importance need considering; for example, how do you compare weeds new and not yet serious in Australia, but known to be important in other countries, with widespread weeds of relatively moderate severity? And of course, the likely effects of climate change need to be considered.

The team also cautions against trusting completely in a system such as this framework and emphasize the importance of some "pragmatic decision making", saying that while it might be tempting to "pick off some of the easier targets first" there can be good reasons for embarking on less promising biocontrol initiatives, for example where there are no alternative control options for a serious invader [as the Old World climbing fern article, elsewhere in this issue, demonstrates].

Although the framework was developed for Australia, it could potentially be used by any country to rank weed biocontrol targets, although each would need to collate data on the importance of each weed and the ease of conducting biological control against it first.

The project was funded by Land and Water Australia as part of the Australian Government's Defeating the Weed Menace Programme.

Source: Anon (2009) Deciding which weeds to target for biocontrol. *What's New in Biological Control of Weeds* No. 48 (May 2009), pp. 5–7. Landcare Research New Zealand Ltd 2009.

The full report is available at: www.lwa.gov.au/weeds

Rabbits and the Danger of Ignoring Rebounds

The news that a benign endemic calicivirus limiting the efficacy of RHDV (rabbit haemorrhagic disease virus, or rabbit calicivirus) in Australia has been identified, coupled with announcement of government funding for screening new virus strains for introduction, make some welcome news. Although rabbit numbers have been on the increase in recent years, funding for biological control research has been in a trough and progress therefore stymied. Researchers have been arguing that advances in biological control are years in the making and a pre-emptive rather than reactive approach to rabbit management is needed.

The history of the rabbit in Australia gives an indication of why its control is a formidable task. Rabbits arrived in Australia with the first European colonists and from when 24 rabbits were released for sport hunting near Geelong, in Victoria, on Christmas Day, 1859, the rabbit has never looked back. By 1926 there were estimated to be ten billion rabbits in Australia. Its rate of spread was the fastest of any colonizing mammal anywhere in the world. By 1886 it had spread north as far as the Queensland–New South Wales border and by 1900 had reached Western Australia and the Northern Territory. It remains Australia's most widespread and destructive pest animal despite the introduction of successful biological control agents such as RHDV, and earlier the myxoma virus.[1,2]

Ups and Downs of Rabbit Control

While most people rejoiced when the release of RHDV in Australia in the mid 1990s was followed by a large reduction in rabbit populations, rabbit researchers were more circumspect. They had seen it all before. Sure enough, evidence emerged first of patchy suppression by the virus and then that rabbit control by RHDV was weakening. Recent publications reviewing rabbit[3] and vertebrate[4] biological control in Australia considered history, and spelt out the current options and the potential consequences of doing nothing.

Going back to the middle of the last century, physical and chemical measures had failed to make an impact on rabbit numbers. Only when the myxoma virus was introduced to Australia in 1950 (and insect vectors introduced subsequently to enhance spread) were rabbit numbers and damage substantially reduced. Numbers were reduced by 95–100% in most of southern Australia after the disease was introduced, and most successfully where the disease's vector insects were abundant. Post myxomatosis, average rabbit density was estimated at 5–25% of the pre-1950 levels, depending on climatic conditions. This had a positive long-term impact on agriculture, and rabbit numbers have never again reached pre-myxomatosis levels. Nonetheless, they are currently estimated to cost livestock and cropping agriculture some Au$200 million each year.

Rabbits had a devastating impact on natural vegetation and thus the native fauna. By competing for food and cover/burrows, rabbits displaced native fauna, and are implicated in the local extinction of some native species. Loss of vegetation can also lead to severe erosion of Australia's relatively infertile soils and reduce biodiversity. Myxomatosis had a more transient effect on the environment than agriculture because natural regeneration has a far lower damage threshold. Emergence of resistance to myxomatosis allowed rabbit numbers to increase so that regeneration of native species was halted about ten years after introduction of the virus and vectors. A decade on from the introduction of RHDV, and it is the same story. Rabbits appear to be developing resistance to infection with the Czech strain 351 (CZ 351) of RHDV that was introduced, and rabbit numbers have increased over the last 6–7 years. In many areas densities are once again sufficient to reduce biodiversity.

Australian researchers have also made substantial efforts to develop new complementary approaches to rabbit control[5]. Fertility control in a species like the rabbit has obvious appeal but despite strenuous attempts to make immunocontraception into a viable control measure, researchers were ultimately unsuccessful.

"Natural Vaccine" for RHD

Early on, scientists realized that RHDV was not uniformly effective across the country, and in particular it was less effective in cool, high-rainfall areas. They suspected from antibody responses that another, non-lethal, calicivirus was responsible. Now Tanja Strive from CSIRO Entomology and the Invasive Animals Cooperative Research Centre (IA CRC) has confirmed this by demonstrating that some rabbits in these areas carry a benign virus that gives them immunity to RHD. The newly discovered, endemic virus has been named Rabbit Calicivirus Australia1 (RCV-A1).

An ancestral form of this virus was probably brought to Australia with the first rabbits 150 years ago. Although its existence was suspected, tracking it down was a 'needle-in-the-haystack' search, as Strive's team had first to identify which areas in Australia were affected, and then where in the rabbit the virus lurked, at what age rabbits became infected, and in which season the virus was active. They eventually found the benign virus in rabbit intestinal tissues and believe it has a faecal-oral mode of transmission.

The CEO of the IA CRC, Professor Tony Peacock, said rabbits are flexing their muscles again and pointed to both the cost to Australia's agricultural industries and the severe environmental damage they cause. Just two rabbits per hectare can be enough to stop plant regeneration. He explained why the discovery of the new virus had important implications for ongoing and future rabbit control. In the short term, at least, rabbit control strategies in affected areas will need to focus on integrated control, using available methods such as chemical baiting, the *Myxoma* virus and warren destruction.

Moreover, it will be necessary to use any existing window of opportunity to apply the lethal RHD calicivirus more effectively and better target eradication attempts on affected populations.

Professor Peacock also pointed out that there is a need for more research to understand where this RCV-A1 virus is and how it acts, so researchers can develop new strategies to overcome this problem and maintain benefits of biocontrol in the future. He emphasized that the discovery of the virus makes it essential to continue developing and improving rabbit control options to reduce their impact and improve ecosystem management.

Additional funding for rabbit research from the Australian Government and industry partners is a significant first step.

RHDV Boost Project

The Australian Government has offered Au$1.5 million to the IA CRC towards the project RHDV Boost, which will import and evaluate additional RHDV strains with the aim of improving rabbit biocontrol. Further funding for this three-year project is coming from Meat and Livestock Australia, Australian Wool Innovation, and Rabbit Free Australia, with significant in-kind contributions from NSW (New South Wales) Department of Primary Industries and CSIRO (Commonwealth Scientific and Industrial Research Organisation).

RHD Boost aims to identify new RHDV strains with high lethality to rabbits immune to the endemic RCV-A1 and to rabbits resistant to infection with CZ 351-derived RHDV strains. The project is a strategic response to the apparent rising genetic resistance to the RHDV CZ 351 strain released in the 1990s, and its limited effectiveness in temperate regions owing to the endemic RCV-A1. Prospects for this are promising, as in Europe, new RHDVa strains are outcompeting the original RHDV strains in the field and strongly suppressing wild rabbit populations in cooler, wetter regions.

Evaluating the new candidate RHDV strains will include screening to determine which candidate RHDV strains overcome rabbits with immunity to CZ 351-derived RHDV and RCV-A1, and research to confirm the competitive advantage of the new candidate RHDV strains. A decision framework to optimize the impacts from releasing candidate RHDV strains will also be developed.

[1]Invasive Animals CRC:
Web: www.invasiveanimals.com

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Dung Beetle Project: the Ball is Rolling

On the 26 June 2009, the Dung Beetle Release Strategy Group (DBRSG) in New Zealand was informed by the MAF (Ministry of Agriculture and Forestry) Sustainable Farming Fund (SFF) that the dung beetle project led by Shaun Forgie and Landcare Research had been approved. Forgie and Hugh Gourlay were successful in obtaining funds of more than NZ$660,000 over three years for this project which carries with it potentially huge benefits for the New Zealand agricultural environment through dung removal, nutrient cycling and pastoral productivity, nitrogen emission reduction, fly and livestock gut parasite control, waterway eutrophication, etc., on land used intensively by livestock.

It might be seen as a little unusual for this sort of project to be run out of Landcare Research, but Forgie has had a long-term interest and expertise in dung beetles, and Gourlay is the master at convincing rural folk to part with their cash. We therefore took the initiative.

Funding from SFF is combined with significant in-kind and financial support from Landcare Research, Auckland Regional Council, Rodney District Council and several companies in the agricultural sector, including Meat and Wool and Dairy NZ. The DBRSG committee for this project comprises a good mix of farmers and organization and iwi representatives mainly from the Rodney District where the initial releases of dung beetles will be made

Some Economics

Losey and Vaughan[1] formulated *conservative* estimates that services provided by dung beetles alone are worth approximately US$380 million annually to the US economy. This value is based on an estimated 32 million head of cattle out of a total of 100 million head in production each year; the faeces from which are available to dung beetles year round and do not contain residual anthelmintics (e.g. avermectins) dangerous to dung beetles. In contrast, New Zealand has nearly 10 million head of cattle, of which 4.6 million are dairy cattle, in production per year[2]. Of these more than 90% are treated with drenches[3]. Assuming equivalent benefits, dung beetles could be worth US$4.2 million (NZ$7.2 million) per year to the New Zealand economy. However, with reduced dependency on drenches following a nationwide establishment of dung beetle populations, their value could reach at least NZ$55 million annually. Dung beetles would also provide the same services to sheep, horses, deer, goats and pigs.

The estimated cost of parasitism in sheep alone in New Zealand is about NZ$300 million/year in lost production and drench use[4]. Adult roundworms live in the sheep's gut and produce eggs, which are passed out with dung onto pasture. Over the next few days to several weeks, depending on moisture and temperature, the eggs hatch and develop into larvae. These larvae climb up moist grass and are eaten by grazing sheep. Certain species of dung beetle are capable of removing up to 74% of eggs and larvae in dung via incidental damage and destruction of these stages during dung burial and mastication of infected dung by feeding adult beetles and their young[5]. Introducing fast-dung-burying beetle species with this ability and suitable to New Zealand's varied pastoral habitats could prove to be economically valuable.

New Zealand's Dung Beetles

While New Zealand has 15 endemic dung beetles that occur mainly in undisturbed native forest with one species in high country tussock habitats, it lacks native pastoral dung-burying beetles. A tropical species, *Copris insertus,* was introduced in 1956 but only established at Whangarei, probably due to poor climate matching. Two accidentally introduced Australian *Onthophagus* species are widespread but have little impact, presumably because they are too small, do not achieve high densities and/or are poorly adapted to feed on pastoral dung.

Benefits of Dung Beetles

Introducing a multitude of efficient dung-feeding generalist beetles into New Zealand that utilize both ruminant and non-ruminant dung has a number of potential benefits including:

- Improving the effects of pastoral earthworms on soil health through increased aeration and water/urine penetration into the soil via beetle tunnels reducing microbial contamination, leachate pollution, and eutrophication of waterways.
- Reducing nitrous oxide emissions because good densities of larger-sized dung beetles that bury dung rapidly can bury up to 90% of dung falling on pasture.
- Increasing pasture availability because dung pats do not stay on the surface long enough to increase forage foul. (Unless forced by farmers stock will not graze around dung pats because of its repulsive nature. Would you?)
- Reducing infection of livestock by parasitic worms, the infective stages of which live in dung.
- Reducing the need for artificial fertilizer inputs through increased nutrient recycling.
- Reducing fly pests and human disease because nuisance flies breed in dung. New Zealand has a very high rate of seasonal, sporadic campylobacteriosis compared to other OECD (Organisation of Economic Co-operation and Development) countries (up to 14,000 cases reported each year). Cattle dung and flies are believed to be the main source and vector of this disease. In Hawai'i, introduced dung beetles reduced fly emergence from dung by 95%.

Screening Programmes

CSIRO (Commonwealth Scientific and Industrial Research Organisation) in Australia successfully completed a 20-year dung beetle programme that screened and mass released onto its nation's pastures a multitude of suitable exotic dung beetles from around the world. The key screening issues are ensuring that the beetles are specifically pasture (not forest) species and generalist ruminant/non-ruminant dung feeders. The New Zealand programme will be able to benefit from all the groundwork that CSIRO has done.

The Next Step

The first phase of this project will be to select a suite of dung beetles suited for New Zealand's varied climate followed by an ERMA (Environmental Risk Management Authority) application for importation and full mass release. Initial releases in the Rodney District will be followed by nationwide releases on a mix of organic and conventional farms. Momentum leading from this seeding project is expected to build as agricultural community support grows nationwide. Longer-term plans focus on widening establishment via community funding and Foundation for Research Science and Technology-based post-release studies monitoring the impacts of established dung beetle populations.

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IPM Systems

This section covers integrated pest management (IPM) including biological control and biopesticides, and techniques that are compatible with the use of biological control or minimize negative impact on natural enemies.

First Operational Use of Green Muscle® Against Locusts a Success

FAO, the Food and Agriculture Organization of the United Nations, announced in June 2009 that the first operational use of the *Metarhizium acridum**-based biopesticide Green Muscle® against locusts had been instrumental in helping to contain a massive red locust (*Nomadacris septemfasciata*) outbreak in Tanzania. By markedly reducing the infestations in Tanzania, the international red locust emergency campaign prevented a full-blown invasion that could have affected the food crops of around 15 million people in eastern and southern Africa.

The news is welcome not least because operational use of Green Muscle® in Africa has been a long time coming. FAO has in recent years played a significant role in highlighting its potential for locust control and keeping it on policy agendas.

If not controlled, large swarms of red locusts will fly over vast areas of farmland, travelling over a distance of 20–30 km per day and feeding on cereals, sugar cane, citrus and fruit trees, cotton, legumes and vegetables cultivated by often poor farmers. A red locust adult consumes roughly its own weight of 2 g in fresh food in 24 hours. A very small part of an average swarm (or about one tonne of locusts) eats the same amount of food in one day as around 2500 people.

Growing Pains

Green Muscle® was developed through 12 years of collaboration in the CABI-led multi-donor project LUBILOSA (LUtte BIologique contre les LOcustes et les SAuteriaux – Biological Control of Locusts and Grasshoppers), which began in 1989 and finished in 2002. The project looked at more than 160 strains of fungi and other locust pathogens before CABI scientists identified the fungus *M. acridum* strain now used in Green Muscle®. The product consists of fungal spores suspended in a mixture of mineral oils.

The paradox about Green Muscle® has been that although in the past it failed to make the breakthrough into use, the LUBILOSA project itself led to many of the scientific improvements seen in biopesticide science over the last two decades, greatly improving understanding of their use as well as increasing their efficacy. CABI's Dave Moore, who worked on the LUBILOSA project, said that a great many scientific advances were made. To take one example, he noted that while shelf-life of a control product is very important, conventionally, biopesticides were regarded as having very poor shelf lives so it was suggested six months should be aimed for. However, improved formulation of Green Muscle® exceeded this by obtaining a shelf-life of 18 months when stored at room temperatures, and up to five years under refrigeration.

The LUBILOSA project was a collaborative programme executed by CABI with the International Institute of Tropical Agriculture (IITA), Cotonou, Benin, and the Département de Formation en Protection des Végétaux, Niamey, Niger. After it finished, a number of initiatives funded by FAO, and other agencies such as the UK's Department for International Development in central and southern Africa and DANIDA (Danish International Development Agency) in West Africa, provided more and more evidence for the biopesticide's ability to control various locust and grasshopper species. But operational use of Green Muscle® remained elusive. Various factors were involved, including the slow speed of action as compared to chemical pesticides may be unacceptable when crops or pastures are under immediate threat, an inadequate policy framework and lack of secure financing for emergency stocks. For example, the sole commercial producer at the time, Biological Control Products (BCP), South Africa, had little support for promoting the product. To date most of the trials and registrations had to be done separately in each country. More recently, support from the President and First Lady of Senegal, stimulated after desert locusts (*Schistocerca gregaria)* invaded West Africa in 2003, has led to the establishment of a second production facility by the Fondation Agir pour l'Education et la Santé (FAES) based in Dakar, Senegal. FAES is in the process of registering the product in the CILSS (Comité Permanent Inter-Etats de Lutte contre la Sécheresse dans le Sahel) member countries. In the meantime, the government of Senegal has already purchased large quantities for operational use against Sahelian grasshoppers. The first large-scale operational applications were carried out last year on more than 7000 ha of a heavily infested mixture of crop fields and fallow land. Another large-scale operation will be carried out this year. The results of last year's operation were very good with Green Muscle® reducing the grasshopper densities (up to 120 nymphs per m^2) by 85–95%. Moreover, areas treated at a dose of 25 g/ha presented the same density reduction as those treated at the registered dose of 50 g/ha. Though grasshoppers do not often attract the attention of the world press, because they do not invade crops in spectacular swarms, they do cause more damage than locusts on an average yearly basis in places like the Sahel.

Registration authorities recognize that microbial pest control agents are fundamentally different from chemical pesticides, and require special consideration. But, in many countries, microbial pest control agents are still evaluated and authorized following the same system as for chemical pesticides. Using the conventional registration process for microbial pest control agents can pose an unnecessarily high regulatory burden to satisfy inappropriate testing requirements. However, a provisional sales authorization was granted by CILSS for Green Muscle® for desert locust control in June 2001, which was renewed in June 2004. In addition, through BCP's efforts, Green Muscle® has been registered in South Africa, Namibia, Iran, Madagascar, Mozambique, Malawi, Yemen, Sudan and Tanzania and is in the process of being registered in many other African countries, including Ethiopia, Algeria and Egypt.

Coming of Age

In June 2009, surveys carried out in Malawi, Mozambique, Tanzania and Zimbabwe by the International Red Locust Control Organisation for Central and Southern Africa (IRLCO-CSA) and the relevant ministries of agriculture revealed serious red locust infestations, particularly in Tanzania. FAO organized and coordinated the rapid intervention campaign together with IRLCO-CSA, which included the treatment of 10,000 ha of land with Green Muscle®. Aerial survey and control operations continued over the following weeks in Malawi, Mozambique, Tanzania and Zambia, until it was clear that the locust threat was fully under control.

Affected countries launched an emergency appeal to FAO for assistance since they do not have sufficient resources and the necessary equipment to respond instantly to large-scale locust infestations in areas that are difficult to access. Tanzania is one of the first countries at risk as it harbours four out of the eight recognized red locust outbreak areas in central and southern Africa. Senior FAO locust expert Christian Pantenius explained that locust control campaigns are logistically very complex and require timely and well-targeted interventions using the most appropriate tactics to reduce locust infestations and avoid unwanted effects on the environment. He commented that this year's red locust campaign had brought all the important players together in time to prevent a potentially very dangerous situation. The UN's Central Emergency Response Fund contributed nearly US$2 million, under its first ever regional project, which allowed aerial survey and control operations to be launched quickly and effectively, while FAO provided around US$1 million from its own emergency funds.

Locust control interventions in Tanzania focused mainly on three areas: the Ikuu-Katavi National Park, the Lake Rukwa plains and the Malagarasi River Basin. In order to protect large wild animals, including elephants, hippos, and giraffes, in the wetlands of the Ikuu-Katavi National Park, FAO used Green Muscle® to treat around 10,000 hectares infested with adult locusts.

In addition, the World Food Programme organized the airlift of conventional pesticides from Mali to Tanzania, to treat around 4500 ha in the Rukwa and Malagarasi region. The chemicals were left-over pesticides from previous locust campaigns.

FAO Assistant Director-General Modibo Traoré said that the concerted and coordinated effort of all partners involved in the campaign was a model for combating other transboundary pests threatening the region. CABI's Dave Moore expressed the hope that the positive outcome of the first use of a biopesticide on a large scale against a locust outbreak in Africa will lead the way for greater use of Green Muscle® in the future.

To get the most from Green Muscle® it is best to treat land proactively rather than reactively. According to Moore, optimum use of Green Muscle® involves treating the breeding sites, focusing on newly-hatched locusts rather than waiting until they become adults and begin flying between areas. His contention that community-based early-warning systems should aid early intervention is endorsed by Pantenius, who identified as the challenge for the future the establishment of these systems involving wildlife rangers and the farm communities in the vicinity of the outbreak areas to better observe locust developments and organize timely interventions.

*The status of what has been known as *Metarhizium anisopliae* var. *acridum* has been clarified in a recent publication: Bischoff J.F., Rehner S.A. & Humber R.A. (2009) A multilocus phylogeny of the Metarhizium anisopliae lineage. *Mycologia* **101**, 512–530.

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Entomopathogenic Fungi Could Help Reduce White Pine Weevil Damage in Canada

Spruce and pine plantations can be subject to major damage caused by the white pine weevil, *Pissodes strobi*. Since the mid 1980s, this small curculionid has spread in Norway spruce (*Picea abies*) plantations and completely halted the use of this genetically improved fast-growing species in Quebec. This insect is also a threat to white pine (*Pinus strobus*) plantations in eastern Canada. In British Columbia, it causes severe damage to the native Sitka and white spruce (*Picea sitchensis, P. glauca*). The damage caused by this insect occurs in the spring on one-year-old leaders, when females oviposit in feeding punctures. After egg hatch, larvae feed on phloem tissue and kill the current growth on the previous year's tree leader. In July, adults emerge from infested shoots, feed on tender twig bark and eventually move to the soil litter to overwinter.

Besides long-term work to find resistant trees and planting trees under a shade-dominant cover, few tools are available to minimize weevil damage. Mechanical control can reduce weevil damage but this treatment must be carried out by trained workers and repeated annually and is difficult to implement on large-scale areas. In the past, chemical control was efficient but today chemical pesticides are banned from forestry operations and a safe and effective biological control method is lacking. Because the weevil's biology is such that larvae develop beneath the bark of the tree's terminal leader, it is difficult to reach them. It is, therefore, necessary to develop a control method that targets the adults when they are on the leader or in the litter in the spring and fall, and thereby reduce the work involved in silvicultural control efforts.

Scientists from the Canadian Forest Service in Quebec and British Columbia and from the Institut National de la Recherche Scientifique – Institut Armand-Frappier (INRS-IAF) in Quebec have strategically combined their efforts to form the ECOBIOM (Extended COllaboration on Biological control of forest Insects Or pathogenic Microorganisms) team. The aims of this group are to develop biological insecticides from entomopathogenic fungi against different forest pests. In eastern Canada, the team discovered indigenous isolates of *Beauveria bassiana* from coleopteran species and demonstrated the susceptibility of the white pine weevil to these. Using two of these isolates applied directly to the soil, they demonstrated that even after inoculation and incubation at 2°C for four months, the tested isolates succeeded in inducing mortality during the cold period or after the insects were moved to 25°C and 60% relative humidity. The cumulative mortality observed after a three-week period under laboratory conditions was 60% and 88% for the two isolates. Also, after simulating the spraying of a terminal leader, adult mortality for the two isolates was 70% and 90% and this was associated with a reduction of 85% and 50% in the number of eggs laid over a three-week period. One of the isolates was demonstrated to be more virulent under cold room conditions. Consequently, applying *B. bassiana* to the soil appears to be an effective strategy for infecting *Pissodes strobi* adults. In addition, applying *B. bassiana* to terminal branch sections, prior to insect introduction, appears to be a potential strategy for infecting *P. strobi* adults during the oviposition period.

Work done by a western Canadian team on the white pine weevil was oriented toward the use of *Lecanicillium* species previously isolated from dead adult *P. strobi*. In order to find the most effective isolates to control the weevil, the researchers confirmed the virulence of 27 fungal isolates of the genus *Lecanicillium*, which occurs naturally in the weevil's environment in British Columbia. Their work showed that, depending on the isolate used, adult mortality varied from 20% to 100% under laboratory conditions. The most efficient isolates took between seven and ten days to kill 50% of the treated insects. Moreover, the researchers noted that the infected weevils could transmit the fungus to other healthy individuals. The ground litter environment supports the survival of fungi, and this approach could, therefore, reduce the populations when they gather under tree litter.

The next step in developing a bioinsecticide against the white pine weevil is to improve the technique in order to use the best isolates in a natural environment.

This research is part of the Integrated Pest Management Project of the Canadian Forest Service (Natural Resources Canada) and was partly supported by the Spray Efficacy Research – International (SERG Project #2005/03).

Further Reading

Kope, H.H., Alfaro, R.I. & Lavallée, R. (2006) Virulence of the entomopathogenic fungus *Lecanicillium* (Deuteromycota: Hyphomycetes) to *Pissodes strobi* (Coleoptera: Curculionidae). *The Canadian Entomologist* **138**, 253–262.

Trudel, R., Lavallée, R., Guertin, C., *et al.* (2007) Potential of *Beauveria bassiana* (Hyphomycetes: Moniliales) for controlling the white pine weevil, *Pissodes strobi* (Col., Curculionidae). *Journal of Applied Entomology* **131**, 90–97.

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Announcements

Are you producing a newsletter or website, holding a meeting, running an organization or rearing a natural enemy that you want biocontrol workers to know about? Send us the details and we will announce it here.

Chromolaena and Parthenium Workshops in Kenya

The 8th International Workshop on Biological Control and Management of *Chromolaena odorata* and Other Eupatorieae, and a Workshop on Management of *Parthenium hysterophorus* are planned for Nairobi, Kenya, in October 2010. Expressions of interest are requested by 30 September 2009. A form can be downloaded from the IOBC *Chromolaena odorata* Working Group (WG) website or by contacting the WG convenor, Costas Zachariades (see below).

The *Chromolaena* workshop is being organized under the auspices of IOBC (International Organization for Biological Control of Noxious Plants and Animals), and will be hosted by CABI. This workshop series was initiated in 1988 to facilitate the management and biological control of *C. odorata* in resource-poor tropical and subtropical countries. In 2003 the scope of the workshop was expanded to include closely related species such as *Mikania micrantha*, while retaining an emphasis on the tropics. Kenya has been selected as the host country for this 8th workshop, the third held in Africa, because *C. odorata* has recently been recorded there and in other countries in East Africa for the first time. The entire region has been shown to be highly climatically suitable for the weed. Because tourism is the main foreign currency earner in Kenya, and the biggest employer is the agricultural sector, the threat of *C. odorata* is very real.

Other species of invasive alien plants which could be included in this workshop, if the interest exists, include *M. micrantha* and *Ageratina adenophora*. Suggestions for discussion on further species of Eupatorieae are welcome.

The *Parthenium* workshop was prompted by the fact that *P. hysterophorus* is spreading in Africa and Asia, causing similar problems to those already experienced in Australia and India, by impacting on agriculture (crops and grazing), biodiversity conservation, and human and animal health. Research on parthenium weed and its management has been conducted over several decades in Australia and India. In Africa, awareness of parthenium weed is limited, but currently some research efforts on the impacts and management of this weed are being undertaken in South Africa, Ethiopia and Uganda, through various nationally-supported programmes and/or international initiatives. Research on the weed is also being undertaken in Pakistan, Bangladesh, Nepal and Vietnam as well as Australia and India. In 2009 an International Parthenium Weed Network (IPaWN) was initiated, coordinated by the University of Queensland, Australia. The intended purpose of the *Parthenium* workshop in Nairobi is to bring together international researchers working on parthenium, to disseminate information on the weed and its management, and to increase collaboration amongst researchers regionally and globally, to optimize resources for the control of this weed. Additionally, it is hoped that this workshop will raise awareness of parthenium weed for countries that are at risk, or that are in the early stages, of invasion by this weed.

Although there are commonalities between the two weed species, many of the issues are specific. Therefore it is proposed that these two workshops run back-to-back with one overlapping day.

Further Information

Expressions of interest are requested by 30 September 2009. The form can be downloaded from the IOBC *Chromolaena odorata* WG website (see below) or:

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New Chromolaena Website

South Africa's Plant Protection Research Institute (PPRI) has developed a new website to act as a portal of the IOBC WG on *Chromolaena odorata*:
www.arc.agric.za/home.asp?pid=5229

The website focuses on the biological control of *C. odorata*, noting that comprehensive coverage of the distribution and ecology of the plant is available through the Invasive Species Specialist Group database. However, in line with a trend evident at the last two International Workshops, it also incorporates basic information (and links for more) on other New World Eupatorieae that have become invasive in tropical and subtropical regions.

Biocontrol Focus in Agricultural Research Magazine

The July 2009 issue of the excellent *Agricultural Research* magazine (Vol. 57, No. 6) has a focus on biological control research being conducted by USDA-ARS (US Department of Agriculture – Agricultural Research Service). Some of the projects described are covered in the General News section of this issue, others have been the subject of past articles, and we hope to cover more in future *BNI* issues.

The complete content of the July 2009 issue is:

- Forum – Overseas labs play vital role in U.S. biocontrol efforts
- Formidable fungus goes toe to toe with kudzu
- Tiny moth tackles Old World climbing fern
- Munching on garlic mustard: a new weevil in the works
- Tackling a trio of tropical troublemakers: Hawaii scientists fight invasive banana moth, white peach scale, and nettle moth
- Biocontrol battle begins against giant reed (*Arundo*)
- Combating the brown marmomated stink bug: a new threat for agriculture, a nuisance for homeowners
- Luring *Varroa* mites to their doom (also in Spanish)
- Pepper compound mighty against mold
- Controlling fire ants takes a group effort
- Western juniper and cheatgrass: scientists probe invaders' evolutionary strategies

• Genotype exploration is key to controlling rush skeletonweed

• ARS Biocontrol Research Program

Agricultural Research magazine is published by USDA-ARS. Articles can be downloaded as PDF or html files. For this issue, see:
Web: www.ars.usda.gov/is/AR/archive/jul09/

Publications from FAO Forestry

Two new publications from the Forestry Department of FAO (Food and Agriculture Organization of the United Nations) deal with forest health.

• Understanding the state of global forest health requires international cooperation and the gathering and dissemination of accurate and timely information. As part of the Global Forest Resources Assessment 2005 (FRA 2005), countries reported on areas affected by insect pests, diseases and other disturbances. This information was supplemented by a thematic study reviewing forest pests in 25 countries. The resulting publication, *Global review of forest pests and diseases* (FAO Forestry Paper No. 156, 222 pp.) therefore represents a rare effort to address forest pests and diseases comprehensively at the global level. In the Part 1 it provides analyses globally and by region. Part 2 contains separate profiles for 22 insect pests and five diseases, while Part 3 deals with 21 selected forest species and their pests and diseases.
Web: www.fao.org/docrep/011/i0640e/i0640e00.htm

• *Climate change impacts on forest health* (Forest Health and Biosecurity Working Papers FBS/34E, 38 pp.) reviews the current state of knowledge on this topic and the implications of these impacts for forest health protection and management.
Web: ftp.fao.org/docrep/fao/011/k3837e/k3837e.pdf

Print versions of both publications are also available from: Sales & Marketing Group, FAO, Via delle Terme di Caracalla, 00153 – Rome, Italy.
Fax: +39 06 5705 5137

Further information and feedback: Gillian Allard, Forestry Officer (Forest Protection and Health), Forest Management Division, Forestry Department, FAO, Via delle Terme di Caracalla, 00153 – Rome, Italy.
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BCPC Congress Relaunched

The BCPC (British Crop Production Council) Congress is once again taking place, on 9–11 November 2009 in Glasgow, Scotland, being organized through a partnership between BCPC and UBM (owner of Farmers Guardian, Informex USA, CPhI and Food Ingredients). The organizers say that research investment and commercialization continue to challenge the scientific community and this will be one of the main themes of this year's BCPC Congress.

For *BNI* readers, sessions of particular interest include: The environment, climate change and the effects on global agriculture; Integrated pest management, Invasive aliens; and Biofuels: examining the consequences for global food production.

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Global Biosecurity 2010

An international biosecurity conference will be held on 28 February – 3 March 2010 in Brisbane, Australia. Global Biosecurity 2010: "safeguarding agriculture and the environment" is Australia's first international conference and exhibition to focus on agricultural and environmental biosecurity. It expects to attract stakeholders from across the biosecurity spectrum, including researchers, industry representatives, policy makers, primary producers and importers/exporters. Conference streams will examine:

• Drivers: what makes biosecurity so important?

• Threats and impacts: understanding risks is the first step in analysing and planning to address biosecurity issues.

• Knowledge: accessing the right information at the right time can be a challenge, with so many agencies and organizations involved across the biosecurity continuum. What information is available, how are you sharing it and what systems underpin it?

• Systems: policy, regulation and operational procedures underpin all biosecurity planning and responses. Is a best practice approach possible?

Web: www.globalbiosecurity2010.com