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General News

David Greathead

As this issue went to press we received the sad news of the untimely death of Dr David Greathead at the age of 74.

Besides being a dedicated and popular Director of CABI's International Institute of Biological Control (IIBC), David was the driving force behind the establishment and development of *Biocontrol News and Information*. He was an active member of its Editorial Board, providing advice and ideas right up to his death.

We plan that the next issue will carry a full obituary. Please contact us if you would be willing to contribute information: commentary, personal memories or anecdotes on the contribution that David made.

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Figures Scotch Beekeeepers' Fears

Potential non-target attack issues and beekeepers' fears are being brushed away as new Scotch broom (*Cytisus scoparius*) biocontrol agents are approved for New Zealand.

Scotch broom is one of the worst invasive weeds in New Zealand, affecting farming, forestry, conservation and amenity values. An application to New Zealand's Environmental Risk Management Authority (ERMA) was recently made by the Canterbury Broom Group (a collaborative stakeholder group, who contracted Landcare Research to prepare the submission) seeking to import and release new biological control agents for Scotch broom, namely, a chrysomelid leaf-beetle *Gonioctena olivacea* and an oecophorid stem-tying moth *Agonopterix assimilella*.

Both agents are narrowly oligophagous, with the potential to develop on a few closely related plant species within the tribe Genisteae, and both showed a clear preference for broom during specificity testing. New Zealand has no native members of the Genisteae, so these agents pose little threat to native New Zealand plants. Nevertheless, the application was complicated because of the risk of non-target damage to tagasaste (tree lucerne, *Chamaecytisus palmensis*), an introduced plant that is closely related to Scotch broom. In New Zealand, tagasaste is planted for soil stability on marginal hill country and is a minor fodder crop, currently planted on only *c.* 30–50 ha of summer-dry pastureland but with the potential to be planted over 5,000–10,000 ha. In addition, broom is a good source of pollen for the beekeeping industry and beekeepers were concerned that a reduction in broom might affect their livelihoods. Both broom and tagasaste pods can be a seasonally important food source for kererū (an endemic pigeon, *Hemiphaga novaeseelandiae*), particularly in regions where its native food plants have declined. A previous petition for the release of *G. olivacea* into New Zealand was rejected by the New Zealand Ministry of Agriculture and Forestry in 1998 on the grounds that there was insufficient information to assess the relative beneficial and harmful effects of the proposed introduction.

As part of the submission to ERMA, Landcare Research quantified the expected costs and benefits associated with the introduction of additional biological control agents for broom[1]. Due to uncertainties regarding the costs, a risk-averse approach was adopted by assuming a worse-case scenario where tagasaste was planted to its maximum potential extent in New Zealand (10,000 ha), levels of non-target damage to tagasaste were similar to those on *C. scoparius*, and no pollen sources suitable for beekeeping would replace broom stands. Due to uncertainties regarding the level of control that will be achieved, a single best estimate for overall benefits of the proposed programme was estimated using an average of four potential biocontrol scenarios: no control, and 25%, 50% or 95% reductions in broom, weighted according to the success rate of past biological control programmes against legume weeds worldwide.

Even though a worse-case scenario was assumed, for costs, the benefits were estimated to outweigh costs by approximately 3:1, with an annual net benefit to New Zealand of NZ$5.99 million. Using discounting techniques over 50 years, an internal rate of return of 52%, and a net present value of $61.49 million was calculated at the 5% discount rate and $21.95 million at the 10% discount rate. These returns are robust to significant overestimation of benefits and to significant underestimation of costs.

The potential cost of mitigating non-target damage to tagasaste (spraying plants with insecticide or planting alternative species) was relatively minor for all scenarios. However, the annual cost of mitigating reduced pollen availability to beekeeping (moving hives or feeding pollen supplements or substitutes) was estimated to reach $2.41 million if broom was reduced by 95%. Landcare Research therefore conducted additional work to investigate the potential impact of broom control on the beekeeping industry.

Flowering broom stands were sampled fortnightly, nationwide, over two flowering seasons. Broom flowers have to be 'triggered' open for bees to gain access to pollen, which enabled the proportion of flowers that had been pollinated at any one time to be assessed. The overall proportion of triggered flowers averaged *c.* 40% and ranged from 8 to 80% (peak fortnightly values ranged from 10 to 89%), indicating that the impact of reduced broom pollen availability on bees is likely to vary according to site. However, it does appear likely that even a minor reduction in broom abundance could result in periods of pollen shortage for bees at some sites. Nevertheless, bees commonly foraged from previously 'triggered' flowers, presumably because 25% of pollen remains after broom flowers are tripped for the first time[2]. Therefore, even at Lincoln, where a small (0.2 ha) patch of broom was surrounded by 16 beehives and a peak of 85% of flowers were pollinated, a 25% reduction in broom cover might not necessarily limit pollen availability to bees.

At two sites, Palmerston North and Lincoln, transects were set up during the broom flowering season and any bees encountered on regular patrols of these transects were followed and all their floral visits recorded. At Palmerston North honeybees were recorded only visiting broom and buttercup, *Ranunculus* sp., with the majority (*c.* 70%) of observations from broom. However, at Lincoln, there was a greater diversity of pollen sources and only 18% of floral visits were to broom flowers. A progression of other species was used: *Sophora* spp. and *Chamaecytisus palmensis* were utilized alongside broom early in the season (October). While bees visited *Teucrium fruticans* heavily in early November, they visited flax *Phormium tenax* and white clover *Trifolium repens* almost exclusively when they came into bloom (mid-November). If these alternative pollen sources increase in abundance, should biological control of broom succeed, this would mitigate the impacts of a reduction in broom pollen availability for honeybees.

As broom is expected to decline gradually, beekeepers also have an opportunity to plant alternative pollen sources to replace broom. Similarly, potentially negative effects to kererū could be also mitigated through appropriate planting of species chosen to provide an alternative food source.

Only two species of pollinator were recorded triggering broom flowers: honeybees and bumblebees *Bombus terrestris*, both of which were introduced into New Zealand. Broom seed rain, which ranged from 59 to 14,443 seeds/m^2, was very closely correlated to the rate at which honeybees pollinated flowers, indicating that, as in Australia[3], broom invasion in New Zealand is being driven by introduced pollinators.

Landcare Research concluded that the potential costs of successful biological control of Scotch broom should not prevent the introduction of additional biological control agents into New Zealand[1]. ERMA agreed, and on 27 July 2006 the release of *G. olivacea* and *A. assimilella* was approved. It is anticipated that the first releases of *G. olivacea* will be made this austral summer.

[1]Jarvis, P.J., Fowler, S.V., Paynter, Q. & Syrett, P. (2006) Predicting the economic benefits & costs of introducing new biological control agents for Scotch broom *Cytisus scoparius* into New Zealand. *Biological Control* **39**, 135–164.

[2]Suzuki, N. (2003) Significance of flower exploding pollination on the reproduction of the Scotch broom, *Cytisus scoparius* (Leguminosae). *Ecological Research* **18**, 523–532.

[3]Simpson, S.R., Gross, C.L. & Silberbauer, L.X. (2005) Broom and honeybees in Australia: an alien invasion. *Plant Species Biology* **7**, 541–548.

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Natural Enemy Unleashed on Buddleia in New Zealand

Buddleja davidii (buddleia) was first introduced to New Zealand as an ornamental shrub and has since become one of the biggest weed problems in North Island forests. A woody species with attractive purple flowers, it has fast growth rates, and outstanding ability to colonize bare ground. Originally from China, buddleia is now considered to be an invasive weed in New Zealand, Australia and Europe.

Buddleia now costs the New Zealand forest industry between NZ$0.5 and $2.9 million annually in control costs and lost production. Its capacity to out-compete young trees makes it a serious problem for forest owners, particularly in the Central North Island. For local and regional authorities in affected areas, buddleia has become a common weed along roadsides. It also represents a nuisance in open areas within native forest reserves, including slips and river beds.

New Zealand scientists at Ensis Forest Biosecurity and Protection[1] have recently unleashed a biological control agent that could assist in managing this serious weed problem. The leaf-eating weevil, *Cleopus japonicus*, was identified by Nod Kay as a potential biological control agent for buddleia and brought into New Zealand for testing in 1993. There followed a long and rigorous testing process enforced by the Environmental Risk Management Authority (ERMA) to ensure that the introduction of this new species would not have a negative impact on the New Zealand environment. Extensive host testing studies determined that the insect only eats buddleia and a *Verbascum* species, which is also an introduced weed.

The release ceremony on Friday 22 September 2006 in Rotorua's Whakarewarewa Forest marked an important milestone for Ensis researchers, government funding providers, the Forest Biosecurity Research Council, and members of the forest industry who have supported this initiative. With the advent of Forest Stewardship Council (FSC) certification the industry is under constant pressure to reduce chemical use, and this biological control initiative demonstrates how forest growers are keen to support serious efforts to find alternatives. New Zealand's government funding body, the Foundation for Research, Science and Technology has also been a key investor over the last decade in the development of the science underpinning *C. japonicus* and will continue to provide funding to support post-release monitoring and research.

The release ceremony included a blessing by a representative of the local Maori people, who are seen as custodians of environmental values in New Zealand. He dubbed *C. japonicus* 'mokai', a Maori word used to describe a pet. Another derivative of this name is 'hemokai' meaning hungry or famished, which seems appropriate to the weevil's new role.

If *C. japonicus* is able to establish successfully in the New Zealand environment, it has the potential to stunt the growth of buddleia through defoliation and enable young trees to out-compete the weed. During its life cycle, each individual weevil consumes a relatively small volume of foliage. For this reason, biological control will only be successful if sufficient numbers of the insect are able to thrive within New Zealand forests. It is anticipated that the weevil will slowly spread into all areas where buddleia is abundant, a process that will be encouraged by further releases in affected forests. Scientists will be monitoring *C. japonicus* population growth closely to assess its rate of increase, and confirm that it is not doing any unintended damage.

The first release of *C. japonicus* marks the start of the next phase of research into buddleia biological control. The weevil will be released at five study sites in plantation forests around the Bay of Plenty and Hawke's Bay. After the initial testing, *C. japonicus* will be made available to regional councils and others.

The current focus of Ensis scientists is on determining how *C. japonicus* survives in the wild, how fast it can spread, and what impact it can have on buddleia in a working plantation. Ecological modelling specialists will be monitoring release sites regularly over a number of years and using the data from this project to develop a better understanding of biological control systems in general. The next stage is to build models that will help predict the likely effectiveness of different biological control agents and increase the probability of choosing agents that will succeed in New Zealand.

[1]Ensis is the unincorporated joint venture between Australia's CSIRO and New Zealand Crown Research Institute, Scion (formerly Forest Research).

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Biological Control Agent Turned Pest Insect

The cactus moth, *Cactoblastis cactorum*, is still an exemplary biological control agent in many parts of the world, but it has fallen from its lofty level to the status of dangerous pest in North America.

During the nineteenth century, *Opuntia* spp. 'prickly pear' cacti were introduced into northeastern Australia as living cattle fencing. They rapidly became major weeds, spreading to cover some 6.5 million hectares of rangeland. Under a classical biological programme, the cactus moth was introduced from Argentina to Australia in 1925. The caterpillars of this moth feed gregariously inside the cactus pad, hollowing it out, and can completely destroy a plant in this way. The introduction was an early success for biological control: the moth spread and controlled *Opuntia* weeds in Australia in a spectacular fashion. As a result it became the flagship programme for classical weed biological control. Cactus moth was subsequently introduced with generally similar success elsewhere, including Hawaii, Mauritius, and parts of South Africa. In a break with previous releases of the cactus moth into areas where all prickly pear species were not native, the insect was introduced to the Caribbean island of Nevis in 1957 against native *Opuntia* spp. From there it was spread intentionally to other islands in the region, and also unintentionally. It is the latter that has led to its fall from grace, because it presents a mounting threat to prickly pears in their native North American habitat.

Opuntia spp. grow throughout the USA and into Canada, but the greatest diversity is found in the deserts of southwestern USA and in Mexico. They are regarded as extremely important plants because of their ecological, agricultural, industrial and cultural value, especially in arid and semiarid regions where few plants can be grown.

- They have significant ecological value, adding to wildlife habitat, ecosystem structure, and biodiversity. They are particularly important to Mexico's desert ecosystems, with 53 species occurring there.
- In the USA they provide emergency forage for cattle during winter months. They are also part of the landscape nursery industry in the western USA and are in limited production for human consumption in California and Florida. Different *Opuntia* spp. produce flowers in an array of colours.
- The cactus is a major agricultural commodity in Mexico, with significant acreage devoted to crop and forage. It is grown as a specialty vegetable, and the pads taste something like green beans. The fruit can be eaten raw or cooked into jams and preserves.

Following its first recorded landfall in continental North America, on the Florida Keys in 1989, *Cactoblastis* moved rapidly along both Atlantic and Gulf coasts. The insect is currently found in peninsular Florida, on barrier islands as far north as central South Carolina, and as far west as Alabama. Until very recently it had not been found in the southwestern USA or Mexico. Then, on 1 August 2006, an infestation was found on the island of Isla Mujeres in Quintana Roo province, on Mexico's Yucatan peninsula. The discovery was made by the Plant Health Directorate (DGSV) of the Secretería de Agricultura, Ganadería, Desarrollo, Rural, Pesca y Alimentación (SAGARPA) as part of the national monitoring programme for cactus moth. The same island was surveyed the previous year and no cactus moth had been detected. The area was heavily impacted by hurricanes that originated in the Caribbean in late 2005, and it had been feared that these powerful weather events might aid the moth's dispersal. *Cactoblastis* occurs in Cuba approximately 160 km from Isla Mujeres. However, the avenue of the insect's arrival in Mexico has not been determined. SAGARPA has dispatched a team to Isla Mujeres to eradicate the infestation and survey other islands and the adjacent mainland for additional infestations. This discovery underlines the urgency of finding more effective ways of halting the moth's expansion.

Since 2003, the USDA-ARS (US Department of Agriculture – Agricultural Research Service) and USDA-APHIS (Animal and Plant Health Inspection Service) have been working with other stakeholders, including The Nature Conservancy, the US Department of the Interior, IAEA (International Atomic Energy Agency), and SAGARPA in Mexico, to implement a strategic plan to halt the cactus moth's westward advance along the Gulf Coast of the USA. Approximately US$1 million annually is being provided by USDA-APHIS and SAGARPA to support the research and control programme in the USA. SAGARPA transferred nearly $0.5 million in 2006 to the USA through the North American Plant Protection Organization (NAPPO).

Sterile Insect Technique

Entomologists from the ARS Crop Protection and Management Research Unit at Tifton, Georgia and the ARS Center for Medical, Agricultural and Veterinary Entomology in Tallahassee, Florida, are studying the use of the sterile insect technique (SIT) against the invasive cactus moth. The goal is to establish a barrier to prevent the westward advancement of *Cactoblastis* along the Gulf Coast, and develop a technology to eradicate isolated infestations.

Moths are mass-reared on an artificial diet, irradiated to induce sterility, and released in large numbers into areas with wild moths so that most matings involve a sterile released insect. The traditional goal of SIT is to overwhelm the pest population with sterile males, which drastically reduces the probability of wild females mating with fertile wild males; if most matings of wild females are with sterile released males, the population produces fewer offspring and numbers fall.

Scientists are taking advantage of a phenomenon in Lepidoptera known as inherited (F_1) sterility to develop a potential management technique for *Cactoblastis*. Female *Cactoblastis* are more sensitive to radiation than the males, so a radiation dose is used that completely sterilizes females but only partially sterilizes males. Sterilized females produce sterile eggs whether they mate with wild (non-sterile) males or partially sterile males. However, partially sterile males that mate with wild fertile females produce eggs in which larval development is reduced, any offspring (F1) that are produced are more sterile than the irradiated adult male, and those offspring are predominately male. Therefore, two advantages are gained in an F_1 sterile SIT programme: (1) the lower dose of radiation increases the quality and competitiveness of the released moths; and (2) any F_1 sterile progeny produced in the field contribute a 'knock-on' effect in reducing population numbers in the next generation. Based on an F_1 sterile field cage study, scientists found that releasing only five times more sterile insects than the number of fertile insects in the field cage was enough to substantially lower the reproduction of the fertile insects. It was also found that releasing both sterilized males and females was more effective than releasing only sterilized males. Sterile females may affect the mating dynamics of *Cactoblastis* by competing with fertile females for mates. Trials are underway at the frontline of the cactus moth invasion on Dauphin Island in Alabama (see below) to test whether a SIT/F_1 sterility programme could serve as a barrier and control technique against the breeding moths.

SIT can be a phenomenally successful technique, with a proven track record against several species of flies, e.g., the screwworm fly (*Cochliomyia hominivorax*) and Mediterranean fruit fly (*Ceratitis capitata*). A 4-year SIT campaign completely eradicated tsetse flies (*Glossina austeni*) from Zanzibar in 1998. SIT/F_1 sterility programmes are also being successfully applied against many economically important Lepidoptera. Current area-wide SIT programmes are underway against codling moth (*Cydia pomonella*) and pink bollworm (*Pectinophora gossypiella*). The use of previously vetted research on such systems allowed scientists to quickly and effectively respond to the cactus moth invasion.

However, SIT's efficacy can be enhanced further when combined with complementary approaches, as other research is beginning to demonstrate.

SIT with Sanitation and Pheromones

The impact of sanitation as a sole or additional treatment with SIT is being assessed. Sanitation involves the removal of cactus pads infested with moth larvae and pupae, and the removal of egg sticks.

Three sites are being evaluated: Dauphin Island, Alabama is receiving sterile insects and undergoing the sanitation procedure. Okaloosa Island, Florida is being sanitized only, and St George Island, Florida is being left untreated as a control site. Results so far indicate that sanitation alone can reduce the wild population of *Cactoblastis*, but the combination of SIT and sanitation is reducing the cactus moth population on Dauphin Island to near non-detectable levels.

A third strand in the programme is the development of pheromone trapping, work underway at the ARS Subtropical Horticulture Research Station in Miami, Florida. An experimental female sex pheromone is being tested as a male attractant in insect sticky traps. These traps are important for monitoring the spread and seasonal activity of the invasive moth.

The prickly pear cactus moth from Argentina has had a varied history. It has been, and continues to be, a dramatic and successful biological control agent in many parts of the world against *Opuntia* spp. As a successful agent, *Cactoblastis* was introduced against invasive, non-native prickly pears. Once the insect was introduced into the Caribbean and it spread into the USA, the insect became a pest attacking native species. The current efforts of USDA and Mexican scientists and regulatory agencies are to develop a method of controlling the destructive nature of *Cactoblastis* on novel host species by limiting the insects' spread. Sustained and additional commitments by federal, state, and environmental agencies will prevent the artificial and natural spread of *Cactoblastis* in the southeastern USA to the western USA and into Mexico.

Further Information

Main source:
Durham, S. (2006) Sticking it to the South American cactus moth. *Agricultural Research* **54**(9), 8–10.
See: www.ars.usda.gov/is/pr/2006/060901.htm

Also: www.aphis.usda.gov/ppq/ep/emerging_pests/cactoblastis/index.html

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The Still-Controversial Cane Toad

The cane toad's is the skeleton that rattles loudest in the classical biological control closet. No matter that the discipline has come a long way since the ill-judged introductions of the 1930s, the cane toad remains a favoured example with biocontrol's critics of the intrinsic rashness of the discipline. It is also a favourite with the popular media: the animals are hideously photogenic.

How apposite it would be if biological control could silence its critics by providing a solution to one of its most embarrassing failures. Although classical biocontrol initiatives have made little progress since surveys were first conducted in Venezuela, in the area of origin of the cane toad, in the early 1990s, no one is admitting defeat. Given the apparent absence of suitable exotic agents, some Australian scientists are taking a 'do-it-yourself' approach and trying to create agents through biotechnology – one promising avenue is discussed below. Another article looks at whether novel bioprospecting approaches in South America might lead us to as-yet undiscovered cane toad pathogens. But while these studies hold out hope for the future the cane toad invasion continues, and efforts to stem it by measures such as trapping and habitat manipulation could benefit from detailed ecological field research. The remaining articles on cane toad in this issue cover some of the ongoing work while, as this issue goes to press, the proceedings of a cane toad workshop held in Brisbane, Queensland in June 2006 are about to be posted online; these provide a comprehensive summary of the current status of Australian research and its application in the war against the cane toad; see:

Web: www.invasiveanimals.com/index.php?id=Publications_Proceedings

The Continuing Saga of Cane Toads and Biocontrol

At a conference of sugar cane technologists in Puerto Rico in 1932 one of the participants, Raquel Dexter, gave a paper describing the stomach contents of 301 specimens of *Bufo marinus* (cane toads or marine toads) that she had captured from sugar cane growing regions across the island[1]. The toads had been brought in from Barbados and Jamaica some 10 years earlier and she reported that 51% of the insects found in those stomachs were "injurious to agriculture" and only 7% were "beneficial forms". In her paper she believed she had contributed evidence to show that *B. marinus* could be effectively used to control the "white-grubs" (*Phyllophaga* sp.) and went on to say that "All other methods of control of this pest [*Phyllophaga*] have so far failed and we strongly advocate the effective use, under favorite [*sic*] conditions, of this amphibian immigrant which is doing its full share of benefit to our sugar industry and to which this International Congress should pay a tribute of gratitude".

So began a long saga which is still unfolding in the tropical north of Australia today. Within one month of the Congress, cane toads had been introduced into Hawaii and 3 years later the Bureau of Queensland Sugar Experimental Stations imported 101 cane toads from Hawaii at the urging of Dr Reginald Mungomery, Director of the Meringa Sugar Experimental Station at Gordonvale, north Queensland, who had been impressed with the positive reports about the effectiveness of cane toads in the West Indies and Hawaii. The danger that cane toads would become a formidable pest in their own right was raised by the President of the New South Wales Naturalist Society, Walter Froggatt, soon after the release but these fears were countered by Mungomery as unjustified opposition to progress[2]. It is easy today with hindsight to be critical of those who began the cane toad invasion in Australia but at that time insects were doing great damage to sugar cane crops around the world and no one had an easy answer to the problem.

Now we have another problem and there is again no easy answer. Cane toads have spread from their original liberation sites and have colonized vast areas of Queensland and the Northern Territory and also the northern coastal region of New South Wales. They are continuing to push westward across the tropical north and within a few years are predicted to enter Western Australia (WA). They will then proceed to colonize the northern end of WA and reach the Indian Ocean coast some time over the next 20 years – and they are also slowly heading south and southwest from Queensland towards New South Wales and northeast South Australia.

So what is the nature of the cane toad problem? Apart from their complete lack of effect on insect pests of sugar cane their main impacts are environmental and social. Their success as an invasive species is presumed to be mostly due to the toxin they produce which is present in all life stages from egg to adult. The toxin is digitalis-like and its action is on the sodium pump present in all animal cells. The sodium pump maintains an electrochemical gradient across cell membranes which allows, for example, muscle cells to contract. The lethal action of the toxin is to stop the heart. Another probable reason for the cane toads' success as adults is that they are generalists when it comes to their food requirements, eating any insect or small animal that comes their way. The females also produce large numbers of eggs, in the vicinity of 30,000 per brood with maybe two broods a year. The tadpole stage is short, some 35 days, compared to native amphibian species and this can give the toad an advantage in temporary water bodies.

They have few predators, either aquatic or terrestrial, that can eat them without succumbing to the toxin. The most obvious impact they have is on the larger native predators such as monitor lizards (goannas), quolls (marsupials) and snakes which usually die within minutes of consuming a toad. In addition, toads compete with other species for food resources and occupy refuge sites that would normally be used by native species. The aboriginal communities in the north are very concerned at the threat the toads pose to some of their traditional food sources such as goannas. Most Australians generally have an aversion to toads and want to see them eradicated. Their presence in both urban and natural wild habitats is resented.

Because of these impacts, albeit largely unquantified, means to reduce their numbers have been sought for many years. In the urban setting many people who have them in their back yards periodically have a blitz on them and remove as many adults as they can from lawns and gardens, and tadpoles from ponds. There are also currently heroic attempts being made at the toad front by the local community to slow down the invasion of toads into WA in anticipation of more effective controls down the track. Although such concerted efforts can have a local impact for a while, these activities are difficult to maintain and have little long lasting effect on populations. Beyond the backyard and in the rangelands off the beaten track the problem is vastly more difficult. Apart from small local areas this invasive species essentially remains unchecked.

If control is the aim then the only possibility for such a species across its current range is to find some form of biocontrol that works while you sleep. This has succeeded spectacularly well for rabbits where two species-specific viruses have been found which have reduced the magnitude of Australia's rabbit problem to some one-third of pre-1950 levels. Unfortunately the search for similar off-the-shelf biocontrols for cane toads has been unsuccessful to date. Cane toads remain an intractable problem.

Making a Cane Toad Biocontrol Work

To address the need for a biological control, CSIRO (Commonwealth Scientific and Industrial Research Organisation) and the Australian Government Department of Environment and Heritage have joined forces to explore the possibility of building a biocontrol agent for cane toads from scratch. The task is an enormously challenging one but with modern molecular techniques it might be possible. The task is simple in concept but difficult in practice. The idea is to take an existing amphibian virus and insert into it a gene that when expressed would interfere with some life stage of the cane toad such that the population is drastically reduced. It needs to be species-specific and transmissible. To date the research team have identified several candidate genes and are using a model virus in a contained environment to deliver these genes to cane toads. In inoculation studies using the product from one of these genes it is possible to show some interference with metamorphosis but there is still a long way to go before an acceptable product can be produced. There is also the obvious need to proceed cautiously with new technologies to avoid the risk of another unfortunate introduction.

Other ideas being pursued by other groups are to see if one could change the sex ratio of cane toads. One is daughterless technology that is being explored for invasive carp control and another, sterile male technology. Although these technologies can be demonstrated in a laboratory setting, the means of disseminating the trait amongst cane toads in the wild is unclear. A search is also being re-kindled to see if there are any other possible infectious agents of cane toads that have been missed in previous searches (see 'Cane toad could play canary', this issue).

There is a contrary view to the idea of biocontrol and that is to do nothing. There is accumulating evidence that native species will adapt and cane toads change to the point where their impact will be acceptable or at least tolerable. There is good evidence that native species learn to avoid toads and also that snakes are changing to adapt to toads. Nevertheless, the outcome of this co-evolution is uncertain and will probably take millennia to play out. In the meantime toads will continue to take their toll and little will be learned in the bigger picture of how to develop effective and safe controls not only for cane toads but for a range of invasive species that continue to reduce the biodiversity of Australia's unique flora and fauna.

Further Information

[1]Dexter, R.R. (1932) The food habits of the imported toad *Bufo marinus* in the sugar cane sections of Porto Rico. Fourth Congress of the International Society of Sugar Cane Technologists, San Juan, Puerto Rico, pp. 1–6.

[2]Lever, C. (2001) *The cane toad. The history of a successful colonist.* Westbury Publishing, Otley, West Yorkshire, UK.

Web: www.feral.org.au/feral_documents/CaneToadReport2.pdf

www.ento.csiro.au/

www.canetoads.com.au/

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Toads Speed on Roads

"The *only* way to travel! Here today – in next week to-morrow! Villages skipped, towns and cities jumped – always somebody else's horizon": words uttered by Mr Toad in Kenneth Grahame's 1908 classic, *The Wind in the Willows*.

Now it appears he is not the only toad to revel in the speed of movement afforded by highways and byways. A 2006 study[1] on the invasion front of cane toads in northern Australia provides the first empirical demonstration that roads and other corridors of open habitat are an important invasion pathway for the toads, and also shows that they can move more quickly on roads than through surrounding vegetated areas. The work has implications for managing the cane toad invasion.

Although there has been a substantial amount of work on the role of roads in the invasion process, this has largely focused on invasive plants which tend to thrive in such disturbed habitats. It is recognized that long, continuous, open habitats are ideal for long-distance movement and facilitate rapid dispersal, allowing invaders adapted to these environments to penetrate unoccupied areas more quickly. Does this apply in the case of the cane toad? In both the native range in South and Central America and in their introduced range, cane toads actively select relatively open habitats. In Australia cane toads are commonly seen on roads, but are they simply more visible there or do they actively seek them out?

To help answer these questions, 9 km of dirt roads and tracks within 2800 ha of the Northern Territory some 50 km east of Darwin were surveyed on some 60% of nights between the end of September 2004 and the end of February 2006. This long-term study area comprises a mosaic of habitat types: seasonally inundated floodplain and lowlands (the wet season is December–March), higher and drier areas of eucalypt woodland and pasture, and some small hills. At the start of the experiment it was still ahead of the cane toad frontline: the first toads were seen in the area on 29 December 2004.

Between February 2005 and the end of the survey, 49 toads were fitted with radio transmitters. They were tracked daily using GPS while they remained in the study area and their locations recorded. The results were striking. All the toads moved consistently in a northwesterly direction, and their dispersal routes overlapped strongly. None of the tracked toads was recorded in a large part of the study area, instead being concentrated in a few linear segments. Superimposing the data on a map of the area showed that these segments corresponded to open-habitat corridors, generally roads or the sparsely vegetated strips beside fence lines (where vegetation is slashed to create firebreaks or stock routes create open corridors). Observations of free-ranging toads on roads in the study area revealed that they were generally positioned facing along the road rather than across it. There was a strong correlation between toad and road bearings, with toads travelling parallel to the main axis of the road.

As the authors here say of their results, "it is difficult to see any alternative to the conclusion that cane toads actively select roads [and fence lines] and follow them." This inference is supported by their observation that several toads made dramatic changes in direction, turning at almost right angles to their previous direction of travel: in all cases these changes occurred at road or fence intersections. A number of reasons for toads preferentially seeking out roads have been put forward over the years; as well as ease of travel, enhanced food availability and feeding effectiveness and thermoregulation have been mooted. The present study confirms the first suggestion, while not discounting the others.

So cane toads do have a partiality for road travel, but do they move faster on them – are roads speeding the invasion? This was investigated by looking at rates of toad movement on two flat substrates: hard packed gravel like the dirt roads in the area, and dense pasture grass, which is the dominant vegetation type and typical of roadside verges. The authors also compared the speed and mode of movement in the first and second metre after release. Overall, performance on the substrates was similar. However, in vegetation cane toads moved more slowly in the second metre, suggesting they tired rapidly from the high leaps they were observed making in an effort to clear the vegetative barrier. In contrast, on the road surface they travelled more quickly in the second metre than in the first, taking more frequent and longer hops, while high leaps were not observed. Closer investigation of tracked toads indicated they travelled on the roads by night, with some of them moving up to 1.8 km in a single night, but remained close to them by day, sheltering in vegetation (typically thick clumps of pasture grass).

Legging It

Another recent paper[2] describes how the annual rate of the cane toad invasion has gathered speed: toads expanded their range by about 10 km/year during the 1940s to 1960s, but are now invading new areas at over 50 km/year. At least part of the reason for this may be down to legs. The authors demonstrated that cane toads with longer legs both move faster over a short distance and move further over 24 hours. Longer-legged toads arrive first in new areas, and toads at the invasion front have longer legs than toads in longer-established populations. This in itself is not so alarming – there is a limit to the speed of even the leggiest toad. Rather, the authors suggest that these rapid shifts in morphology and speed are indicative of rapid adaptive change: evolutionary forces may be fine tuning traits in ways that facilitate invasion. They argue that control efforts should be launched early, before the invader has the time to evolve into a more dangerous adversary.

Speed Traps

The confirmation that cane toads use roads and fence lines as fast-track dispersal corridors suggests means by which initiatives aimed at reducing toad densities or slowing the advancing invasion might be better targeted:

• Collection and removal efforts could concentrate on open habitats – especially roads.

• In the Darwin region, verges are frequently slashed and treated with herbicide to improve visibility and control invasive African grassy species. Retaining dense vegetation could decrease the attractiveness of the verges for toad dispersal and force them onto the road, where they are more vulnerable to trapping, vehicles, etc.

• Allowing vegetation to grow along fence lines would diminish the role of this habitat as a rapid dispersal route.

But there are other factors to take into account and more work is needed:

• Increasing the density of roadside habitat to deflect toads onto the road might have a similar impact on non-target animals, notably native anurans. Species that are largely restricted to roadside habitats would be particularly at risk.

• The impact of verge modifications on invasive plants would also need to be assessed.

• With regard to vegetation management at fence lines, further research is needed to find a balance between impeding cane toad movement and altering fire risk.

• The current study tracked cane toads that were characteristically located in narrow open corridors (perhaps resting in the surrounding vegetation during the day). There is little knowledge of how they react to large open areas.

• Open areas surrounded by dense vegetation may be relatively safe from cane toad invasion. Further measures might enhance this, including minimizing vegetation clearing and blocking paths with toad-proof barriers that other species can still cross.

[1]Brown, G.P., Phillips, B.L., Webb, J.K & Shine, R. (2006) Toad on the road: use of roads as dispersal corridors by cane toads (*Bufo marinus*) at an invasion front in tropical Australia. *Biological Conservation* **133**, 88–94.

[2]Phillips, B.L., Brown, G.P., Webb, J.K. & Shine, R. (2006) Invasion and the evolution of speed in toads. *Nature* **439**(16), 803.

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Spawning Sites: Chinks in the Cane Toad's Armour?

Popular accounts of the cane toad (*Bufo marinus*) invasion of Australia paint it as an invincible beast, but it does have its vulnerabilities. If the weak points in a pest's life cycle can be identified, they may be exploited for its control.

Like many amphibians, the cane toad spawns in water and is very choosy about where it spawns. A recent study[1] suggests that its site preferences may be highly selective and differ from those of the native frogs of Australia, providing potential management opportunities. Precise abiotic and biotic attributes of a water body may govern whether or not a water body is acceptable as a spawning site, and suitable sites can be few and far between. In this study, the authors surveyed water bodies along two highways in an area of Australia's Northern Territory recently colonized by the cane toad. They located 25 sites where cane toads were found to be breeding, and compared them with near-by, apparently similar, water bodies where they were not.

Multivariate analysis of the results indicated a broad similarity in water chemistry and temperature between sites with and without toads breeding in them, suggesting these were not determining factors. Rather, it seemed that water bodies selected by cane toads for spawning were characterized by physical habitat similarities: most were shallow-edged still-water pools containing aquatic vegetation, but with relatively un-vegetated gently sloping muddy banks. Cane toads were noticeably *not* found spawning in flowing water, or where the water was deep close to the bank, the banks were vertical, or surrounding vegetation was dense.

These findings differ in some respects from the results of the only previous cane toad spawning site study, conducted in its area of origin in Venezuela; for example pH and turbidity affected site selection in Venezuela. There are a number of possible explanations which only further studies can unravel.

It is an attractive prospect that by altering some of the attributes that make pools attractive for spawning, it might be possible to reduce cane toad populations at the invasion front in Australia. Work elsewhere on other invasive anurans and crayfish has indicated habitat modification to be more effective as a population control measure than removing adult animals. Given the findings outlined in the article above – that cane toads at the invasion frontline tend to be concentrated on roads and similar open corridors – work focused on the water bodies closest to roads (which are also conveniently easily reached) could have most impact. But further research is needed first. Although modifying habitats to make ponds less attractive might be intuitively expected to affect cane toad populations, this needs careful evaluation before changes are implemented. Potential non-target impacts on native inhabitants of the ecosystem must also be assessed, including the degree of overlap of breeding sites of native and the non-native amphibians.

[1]Hagman, M. & Shine, R. (in press) Spawning-site selection by feral cane toads (*Bufo marinus*) at an invasion front in tropical Australia. *Austral Ecology*.

Contact: Rick Shine (as above).

Developing Tastes for Toads

If an invasive pest is too well established to eradicate, and the invasion too far advanced to contain, what is the next step? Article 8(h) of the Convention on Biological Diversity (www.biodiv.org) urges control, but what is the best strategy? Some argue that with time many invasive problems abate as local factors, including natural enemies, come into play. Others maintain that a rapid response is essential.

The cane toad (*Bufo marinus*) problem in Australia can hardly be said to be abating. Nonetheless, some new studies indicate that, rather than being brought to the brink of extinction, the native fauna is fighting back.

For example[1], black snakes (*Pseudechis porphyriacus*) from localities invaded by cane toads show increased resistance to toad toxin and a decreased preference for toads as prey compared with snakes from uninvaded areas. Have the snakes evolved, or are these learnt traits? Cane toads were introduced in 1935, so snake populations have been exposed to them for at most 23 generations. The toad represents an extremely strong and novel selective force on the snake populations, but can natural selection operate this rapidly?

The results suggest the snake's behaviour and physiology have indeed evolved. The authors could not teach naïve snakes to avoid cane toads, and sublethal doses of toxin did not impart subsequent tolerance. In contrast, an observed steady increase in toxin resistance with the time of cane toad population exposure to toads is evidence for selection. Although a similar trend was not found for prey selection, it is known to be variable and highly heritable in other snakes. There may also be a morphological dimension: previous work related a reduction in snake head size (thus a reduction in maximum prey size) to a history of population exposure to (the large) cane toads. Other evidence indicates cane toads are now smaller and less toxic than when they were first introduced to Australia, so they are also changing.

So – should research into control be put on hold? No, but these results illustrate the importance of considering potential for adaptation when predicting long-term impacts of invasive species, because this will allow priorities to be set and resources to be optimally targeted.

[1]Phillips, B.L. & Shine, R. (2006) An invasive species induces rapid adaptive change in a native predator: cane toads and black snakes in Australia. *Proceedings of the Royal Society, Series B* **273**, 1545–1550.

Contact: Rick Shine (as above).

Cane Toad Could Play Canary

In toad speak, finding an effective cane toad biocontrol will be tantamount to finding the pot of gold under the storm cloud. In Australia where the storm clouds of the monsoonal north bring the toads their life-giving waters and dispersing floods, the need for a biocontrol has never been more warranted. At the June 2006 Cane Toad Workshop in Brisbane, Australia, being told of the 87–92% decline in monitor lizards (*Varanus panoptes*, *V. mertensi* and *V. mitchelli*) along the Daly River, Northern Territory (Sean Doody, University of Canberra) and the localized extinction of a small marsupial, the predatory northern quoll (*Dasyurus hallucatus*; Karen Firestone, University of New South Wales/Taronga Zoo), were significant reminders of impacts this toxic pest animal is having in its relentless invasion across northern Australia. On top of this there are the indirect trophic impacts, such as on nest predation of pig-nosed turtles (*Carettochelys insculpta*) by *V. panoptes*[1,] which more often go unnoticed or unstudied. Though the loss of *V. panoptes* from cane toad poisoning may result in a 20% increase in *C. insculpta* hatchlings[1], and significant increases in other *V. panoptes* prey, this meso-predator release will likely have its own ecological costs on their own prey species. This is what happens in a food web when species at the top are severely impacted and one of the most classic examples is that of the misguided human removal of predators (wolves, mountain lions and coyotes) on the Kaibab Plateau in northern Arizona. In the early 1920s this predator destruction programme was credited by Aldo Leopold as causing a trophic cascade and the subsequent mass starvation of the area's deer[2]. The message from examples such as these is that taking top order predators from an ecosystem will have consequences, obvious or subtle, acute or chronic. For northern Australia, losing many of its monitors and northern quolls would be somewhat akin with a region of Africa losing its lions and scavenging jackals. Then there are the human impacts, as communities at the toad front, facing the prospect of having to live with the aesthetic, environmental and social impacts of these toads, undertake trapping with assistance of NT FrogWatch, or drive 450 km from Western Australia to the Northern Territory toad front to 'bust toads' (www.canetoads.com.au), in the hope of slowing their advance. Although scientists will argue about the degree and longevity of the detrimental impacts by cane toads, there is enough environmental and social cost for Australian society to desire being rid of this toxic pest. But what to do?

When the expanding distribution of an introduced vertebrate pest such as the cane toad covers many thousands of square kilometres, biological controls are our only real hope for some degree of control. This was recognized early in the battle to control this pest. When your pest animal is the continent's only representative of its genus, the options for biocontrol grow from the more generally preferred species-specific to the possible genus-specific. The difficult task then is to locate an agent, or with modern genetic engineering, try and create one. In essence this is the division in the search for a cane toad biocontrol, a natural agent or a man-made one. The original approach was for a natural agent and thus from 1990 to 1993 a search was made of cane toads in Venezuela and Brazil for potential biocontrol agents. This resulted in isolation of a number of viruses from the genus *Ranavirus*. Unfortunately, although these viruses have many benefits, they have been found to be non-specific, even causing high mortality in the native fish, barramundi (*Lates calcarifer*). Because of this lack of success in finding a natural biocontrol agent, CSIRO research has continued with the man-made approach. Current research now seeks to develop a recombinant ranavirus in the hope of developing a genetically modified virus with the capacity to selectively inhibit cane toad tadpole metamorphosis [see 'The continuing saga of cane toads and biocontrol', this issue].

Another modern man-made hope for a cane toad biocontrol lies in a sex skewing strategy to genetically manipulate cane toads to produce only male offspring. This 'daughterless cane toad' research somewhat mirrors current daughterless carp (*Cyprinus carpio*) research. Both the sex skewing biocontrol strategy and a proposal to control the toads through the development of sterile (triploid) males have the essential requirement of annually swamping a population's healthy virile individuals with the genetically altered toads. Preliminary modelling presented at the Cane Toad Workshop indicated that the likely time to extinction was 75 years and with the sterile male technique, the ratio of sterile males : fertile males needed to be at least 30:1. Success through a strategy requiring such longevity in government policy and logistics, with a species whose fecundity is around 30,000 eggs per female (and the thousands of released toads will still be toxic to the control area's remnant fauna), may have no precedent in modern biocontrol.

Bioprospecting for that Pot of Gold

The search for a natural biocontrol does however continue. In a paper presented at the Cane Toad Workshop this author has accepted the 'potential strategy' outlined in the June 2005 report from the National Cane Toad Taskforce to the Vertebrate Pests Committee[3] in seeking a biocontrol agent for *Bufo marinus* where this species is not present, but bioclimatically suited. So where should we look? Utilizing a published CLIMEX modeling study[4] the Corrientes region of northern Argentina was identified as an area worthy of investigation. Although it has two resident *Bufo* toads in *B. arenarum* and *B. paracnemis*, the ubiquitous cane toad has failed to colonize the Corrientes region, despite having high bioclimatic compatibility, from neighbouring Paraguay. Perhaps there is a biocontrol reason for this absence?

Here a conundrum presents itself: how do you test the hypothesis that a species, the cane toad, is absent from a region because of an unidentified local pathogen? And how do you find that pathogen if it exists? The proposed answer is bioprospecting, using cane toads as pathogen sentries – like canaries in a coal mine. One potential strategy is for South American sourced toads to be brought into a secure facility in Corrientes and kept in toad-proof ponds, where they could be screened against potential pathogens from the local region. In exposing them to the local water and pathogen sources, such as aquatic leeches and arthropods, it would be hoped that toad mortality could be traced to a pathogen source. There is evidence that the avenue is worth pursuing, with a most prominent example being the inadvertent exposure of European rabbits to the myxoma virus (likely from *Sylvilagus brasiliensis*) and the discovery of the myxomatosis biocontrol agent[5]. In particular, in proposing that a search be made of the Corrientes region, it was noted that particular attention be paid to trypanosome blood parasites as *Trypanosoma cruzi*, a nasty generalist cosmopolitan trypanosome, is stated to have experimentally caused the deaths of five of six *Bufo* toads – with the surviving toad having escaped the laboratory! While no one in their right mind would contemplate introducing *T. cruzi* to Australia, this finding could be an indication of an inherent susceptibility of the cane toad to trypanosome pathogens. Extrapolating from this, perhaps the resident *Bufo* toads of the Corrientes region possess a trypanosome parasite which has inhibited the cane toad establishing there (although it may be for other reasons; inter-specific competition for example). There is mounting evidence that anuran trypanosomes can exhibit considerable host specificity, and the absence of any native blood parasites, including trypanosomes, from the introduced Australian cane toad population[6] perhaps presents a gap to be exploited.

Whatever the reason, or reasons, for the inability of the cane toad to inhabit the highly bioclimatically suited Corrientes region of Argentina, it is considered a location worthy of further investigation. Perhaps we will find our proverbial 'pot of gold' in a biocontrol pathogen, perhaps one which will go some way to limiting the distribution, abundance and impact of the cane toad.

[1]Doody, J.S., Green, B., Sims, R., Rhind, D., West, P. & Steer, D. (2006) Indirect impacts of invasive cane toads (*Bufo marinus*) on nest predation in pig-nosed turtles (*Carettochelys insculpta*). *Wildlife Research* **33**, 349–354.

[2]Young, C.C. (2002) *In the absence of predators: conservation and controversy on the Kaibab Plateau*. University of Nebraska Press, Lincoln, USA.

[3]Taylor, R. & Edwards, G. (2005) *A review of the impact and control of cane toads in Australia with recommendations for future research and management approaches.* A report to the Vertebrate Pests Committee from the National Cane Toad Taskforce.

[4]Sutherst, R.W., Floyd, R.B. & Maywald, G.F. (1996) The potential geographical distribution of the cane toad, *Bufo marinus* L. in Australia. *Conservation Biology* **10**, 294–299.

[5]Fenner, F. & Fantini, B. (1999) *Biological control of vertebrate pests. The history of myxomatosis, an experiment in evolution.* CABI Publishing, New York.

[6]Delvinquier, B.L.J. & Freeland, W.J. (1988) Protozoan parasites of the cane toad, *Bufo marinus*, in

Australia. *Australian Journal of Zoology* **36**, 301–316.

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Training News

In this section we welcome all your experiences in working directly with the end-users of arthropod and microbial biocontrol agents or in educational activities on natural enemies and IPM aimed at students, farmers, extension staff or policymakers.

Pioneering Folk Experiments

An unorthodox approach to participatory research has led to many new non-chemical technologies for managing a potato disease recently arrived in the South American Andes[1].

Bacterial wilt caused by *Ralstonia solanacearum* is transmitted by infected seed, soil or even irrigation water. It was first reported in Bolivia in 1984. It is hard for farmers to detect, causes severe crop losses, and there is no effective cure. The key to disease management is to plant healthy seed in disease-free land, especially by rotating crops so that potatoes are grown only once every 5 years on a given plot, but in recent years many Andean smallholder farmers have responded to market demand for more potatoes by growing potatoes more often. Some families have little land, and are forced to grow potatoes on the same plot almost every year.

Between 2001 and 2004 the Integrated Bacterial Wilt Management (IBWM) Project was conducted in Peru and Bolivia by CIP (the International Potato Center) and the PROINPA Foundation (Promotion and Research of Andean Products) in areas where potatoes are the daily staple on family farms and for the urban poor. The project worked largely through CIALs (Local Agricultural Research Committees), in which smallholder farmers are organized into groups, taught scientific methods and participate in adaptive research with agricultural scientists. CIALs are becoming widespread in the Andes and Central America. They were originally conceived to help test new crops and varieties, but the IBWM Project extended this remit considerably. They also linked CIALs with farmer field schools (FFS). FFSs were used as a first step to introduce farmers to the disease and how to deal with it. For example, they learnt they should rotate their crops, and ‘rogue’ (uproot and destroy) infected plants. Through the CIALs they experimented with these and other measures.

Shrinking Rotations

How participants – scientists and farmers – looked for ways to clean the soil and reduce the length of the rotation illustrates the flexible approach of the project.

- Even before he was included in a CIAL, one farmer came up with his own solution. With a single irrigated potato field, he had no choice but to plant potatoes year on year. The disease built up until he was losing most of his crop. Drawing on his FFS training, he invented a method of combining roguing and rotation: he uprooted and removed each diseased plant, and planted wheat seed in the hole in its stead. The first year, he had to replace most of his potato plants with wheat, the second year only 20%, and by the fourth year this was down to 7%.

A particular rich vein of inventions came from agronomists.

- An observation made by a PROINPA agronomist during an earlier stint of laboratory work with CIP led to another innovation: bleach used routinely to wash potatoes before cutting them up did not prevent them from sprouting. Subsequently he worked with farmer CIALs to confirm that either soaking seed in laundry bleach or spraying the bleach in furrows at planting led to healthy potato crops.
- CIP agronomists designed trials to test the effect of rotating different crops in a field with high disease incidence, paying particular interest to another native Andean tuber, arracacha (*Arracachia zanthorrhiza*). Eighteen months on and following three rotations of arracacha, lupine (*Lupinus* spp.), sweet potato or cabbage, a thriving potato crop was raised because so much of the disease inoculum had been eliminated.

Often scientists drew on something learnt from farmers.

- Farmers were asked to dig furrows at the entrance to fields and fill them with lime to prevent field-to-field movement of diseased soil. One village switched to ash because they ran out of lime. When the ash was tested by a CIP pathologist it killed *R. solanacearum* within 2 days in a greenhouse. A CIP agronomist started to design trials to test this further. CIAL members in another village had observed that ash applied as fertilizer (something learnt during an FFS under a previous project) helped control bacterial wilt.

Other ideas being tested under various application methods for killing *R. solanacearum* in the soil include boiling water, fire, detergent, chicken and cow manure, horse urine and plant extracts.

Formal vs Participatory Approaches

The systematic experimentation to evaluate these discoveries that followed used both formal trials and participatory approaches. The experiments had two – not always compatible – objectives: for farmers to understand the results of the experiment and be able to apply them to their crops, and for the scientists obtain the data they set out to.

In formal trials the treatments are chosen by agronomists. They are carried out in fields of CIAL members who provide the labour, although agronomists may not view the trials as part of the CIAL. With replicates of 6–7 treatments arranged in random blocks, formal trials are not easily understood by farmers. Making sure data are accurately collected at harvest needs organizational skills, but with thought the results can be made accessible.

• In the above trial of the various rotations there were three replicates of seven treatments. The agronomists recorded the data from each harvested replicate, then piled the replicates for each treatment in one place. The farmers could see that yields of potatoes from rotated plots, and especially those rotated with arracacha and sweet potato, were much higher than monocropped plot yields.

Participatory experiments are designed in consultation with CIAL members and tend to be simpler with fewer replicates. Blocks are still randomized and agronomists help farmers to collect data. Although farmers understand the reason for the randomized design (land quality varies, even in a small field), they find the design itself bewildering, and may confuse treatments – they are not alone: agronomists keep plans to remind themselves.

Folk Experiments

Farmers learn from working alongside agronomists and also experiment by themselves, often testing ideas they have learnt from agronomists.

• One of the farmers that tried bleach, above, sprayed furrows in as much of his field as he had bleach to spray. He planted a row of maize to mark this point, and planted the rest of his field as normal. Later he showed the scientists the results of his *ad hoc* experiment: only the unsprayed part of the field had developed the disease.

• Another farmer had learnt to make earthworm compost at an FFS. He planted part of his crop with this, and part with humus – his normal practice. From his training he had learnt the importance of including a control to compare with his experimental treatment.

Farmers tend to include two or three variables, usually in a single treatment, and often without a control.

• Yet another farmer planted certified seed in a forest remnant on the edge of a potato field. He cleared the brush and saplings but spared all the mature trees, which he valued. His objectives were (a) to test the agronomists' assertion that virgin soil is disease-free, (b) to find out whether a crop can be grown under light shade and (c) rear seed.

This brings out an important difference in the goals of scientists and farmers: in trials, scientists want data, while farmers want to harvest a crop.

Adopting and Adapting

By adopting the CIAL as a method of organizing people, and adapting its function to allow a number of experimental methods, a range of new technologies were created. That might not have been the case had the more formal trial-based protocol been strictly adhered to.

Further Information

[1]Main source: Bentley, J.W., Priou, S., Aley, P., Correa, J., Torres, R., Equise, H., Quiruchi, J.L. & Barrea, O. (2006) Method, creativity and CIALs. *International Journal of Agricultural Resources, Governance and Ecology* **5**, 90–105.

Web: www.cipotato.org/potato/Pests_Disease/BacterialWilt/wilt.htm

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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.

News from IOBC

IOBC (International Organization for Biological and Integrated Control of Noxious Animals and Plants) published the third edition of the IOBC Internet Book of Biocontrol in March this year:

Web: www.IOBC-Global.org

The aim is to present the history, current status and future of biological control in order to show that this control method is sound, safe and sustainable. Biocontrol workers are asked to support the preparation of the book firstly by supplying summaries of the actual application of biological control in each country or region. The second priority is to document the history of biological control in each country, including some key references, so that it will be easier for all biocontrol workers worldwide to know what has been done and what is going on at this moment. As part of this, IOBC is preparing an overview of biological control books available in the world's various national languages. Those found so far are listed in an appendix. You are asked to send a short summary and a jpeg file of any books missing from the existing list so they can be added.

IOBC are planning a symposium about biocontrol in Africa to be held at the next International Congress of Entomology in Durban (see below).

The IOBC website is managed by the Secretary General, Stefano Colazza. Send any suggestions for additions and improvements to:
Email: colazza@unipa.it

ICE in South Africa

The next International Congress of Entomology (ICE) will be held on 6–12 July 2008 in Durban, South Africa, with the theme 'Celebrating entomology: contributions to modern science'.

Programme sections include: pest management in perennial crops, and in annual crops; pesticides, residues and toxicology; transgenics; forest entomology; stored product and post harvest entomology; ecology; genetics and evolutionary biology; insect pathology; medical and veterinary entomology; reproduction and development; physiology and biochemistry; behaviour and neurobiology; social insects; systematics, phylogeny and zoogeography; conservation, biodiversity and climate change; insect plant interactions; invasive species; and special issues

Suggestions are invited for symposium topics that address the main congress themes, as indicated by these programme sections.

Web: www.ice2008.org.za/

Portal for DFID Research

More than 300 institutions worldwide are involved in research funded by DFID (the UK Department for International Development). R4D (Research for Development) is a free access online database from DFID containing information about these research programmes, together with news, case studies and details of current and past DFID-funded research. It currently includes some 6000 projects conducted since the mid 1990s. Information on projects and outputs can be sought by country, institution and research theme.

Web: www.research4development.info

FAO Forest Invasives Portal

An FAO website and online database was launched in February 2006 to help foresters cope with invasive alien species (IAS). As well as discussions about spread, impacts (positive and negative) and management of IAS in forestry, the site includes an invasive tree species database, links to regional networks in Africa and the Asia–Pacific region, and details of the *Prosopis* programme (with information also on other conflict species). Relevant FAO publications and activities are included, together with a useful section giving international and regional instruments, binding and nonbinding, and programmes that have been developed to deal with the problem of IAS with direct or indirect implications for forests and the forest sector.

Web: www.fao.org/forestry/site/27081/en

Pheromones from Wales

The Cardiff Pheromones website at:

www.cardiffpheromones.com or
www.cardiffpheromones.co.uk

lists a range of insect pheromones kept in stock. The company are happy to discuss annual requirements, and can source traps, lures and dispensers for IPM use. They can also develop a wider range of intermediates and have expertise in the custom synthesis of semiochemicals.

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Journal of Applied Ecology

The October 2006 (43:5) issue of the journal has a special profile on biological invasions. Papers of particular relevance to biocontrol include an editor's perspective, 'Beyond control: wider implications for the management of biological invasions' (Hulme); 'Management of plant invasions mediated by frugivore interactions' (Buckley *et al.*); 'Modelling global insect pest species assemblages to determine risk of invasion' (Worner & Gevrey); 'What controls the population dynamics of the invasive thistle *Carduus nutans* in its native range?' (Jongejans *et al.*); 'Predictors of recruitment for willows invading riparian environments in south-east Australia: implications for weed management' (Stokes & Cunningham); 'Approaches for testing herbivore effects on plant population dynamics' (Halpern & Underwood); 'Seasonal patterns in post-dispersal seed predation of *Abutilon theophrasti* and *Setaria faberi* in three cropping systems' (Heggenstaller *et al.*); and 'Using the stable isotope marker ^{44}Ca to study dispersal and host-foraging activity in parasitoids' (Wanne *et al.*).

Web: www.blackwell-synergy.com/toc/jpe/43/5

Australian Journal of Entomology

The November 2006 (45:4) issue of the journal features weed biocontrol. The editorial, 'Refining the ecological basis for agent selection in weed biological control' (Raghu & van Klinken), is followed by: 'A scientific approach to agent selection' (van Klinken & Raghu); 'Strategies for the biological control of invasive willows (*Salix* spp.) in Australia (Adair *et al.*); 'Biological control of *Parkinsonia aculeata*: what are we trying to achieve?' (van Klinken); 'Ecological studies to assess the efficacy of biological control on populations of alligator weed and lippia' (Schooler *et* *al.*); 'Maximising the contribution of native-range studies towards the identification and prioritisation of weed biocontrol agents' (Goolsby *et al.*); 'Selection of biological control agents for bridal creeper: a retrospective review' (Morin & Edwards); 'Native-range research assists risk analysis for non-targets in weed biological control: the cautionary tale of the broom seed beetle' (Sheppard *et al.*); 'Use of CLIMEX modelling to identify prospective areas for exploration to find new biological control agents for prickly acacia' (Senaratne *et al.*); 'A systematic approach to biological control agent exploration and prioritisation for prickly acacia (*Acacia nilotica* ssp. *indica*)' (Dhileepan *et al.*); 'Refining the process of agent selection through understanding plant demography and plant response to herbivory' (Raghu *et al.*); 'Can an *a priori* strategy be developed for biological control? The case of *Onopordum* spp. thistles in Australia' (Briese); 'Using simulated herbivory to predict the efficacy of a biocontrol agent: the effect of manual defoliation and *Macaria pallidata* Warren (Lepidoptera: Geometridae) herbivory on *Mimosa pigra* seedlings' (Wirf); 'Predicting the response of *Cabomba caroliniana* populations to biological control agent damage' (Schooler *et al.*); 'Predicting population dynamics of weed biological control agents: science or gazing into crystal balls?' (Zalucki & van Klinken); 'Nutrient composition of soil and plants may predict the distribution and abundance of specialist insect herbivores: implications for agent selection in weed biological control' (Schwab & Raghu); and 'Selection of pathogen agents in weed biological control: critical issues and peculiarities in relation to arthropod agents' (Morin *et al.*).

Web: www.blackwell-synergy.com/toc/aen/45/4

Global Invasive Species Database

The Global Invasive Species Database, listing invasive species threatening biodiversity, was launched in May 2006 and is available free online or on CD. Its purpose is to provide expert-originated information to overcome the frequent paucity of reliable data impacts, pathways, distribution, risks and management methods by providing relevant, expert global information.

Web: www.issg.org/database/welcome/
To order CD, email name and postal address to: M.Browne@auckland.ac.nz

New IPM Director, Familiar Biocontrol Face

Dr R. Muniappan is the new Director of the US-based Integrated Pest Management-Collaborative Research Support Program (IPM-CRSP), moving from the University of Guam/Guam Department of Agriculture where he has become best known in recent years for his role in efforts in promoting biological control of *Chromolaena odorata*. These have included producing the *Chromolaena* newsletter, organizing international workshops (the most recent in Taiwan in September 2006; see Conference Reports, this issue), and supporting programmes in the Pacific.

New contact details: R. Muniappan, Director, IPM-CRSP, OIRED, Virginia Tech, Blacksburg, VA 24061, USA.
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Encyclopaedia of Seeds

This book[1] covers all aspects of seed biology (from anatomy to ecology), seed technology (production and processing for crop cultivation) and the use of seeds as sources of a wide variety of products. Biological protection is covered in the section on treatments and enhancements in the seed technology section.

[1]Black, M., Bewley, J.D. & Halmer, V.P. (2006) *The encyclopedia of seeds: science, technology and uses*. CABI, Wallingford, UK, 900 pp. Hbk.
ISBN: 0851997236. Price: UK£185/US$350.
See: www.cabi-publishing.org

Golden Apple Snail Book

A new 600-page book[1], sponsored by DICTUC and FAO, synthesizes all available information on golden apple snails (GAS) and the rice systems and countries they have afflicted – and thus fills a knowledge gap on this important invasive pest which has caused losses of at least US$ 1 billion worldwide.

The book covers various aspects of snail taxonomy (based on traditional as well as molecular tools), impacts of GAS on aquatic ecosystems and farmers' health, and pesticide abuse/misuse. Country reports from GAS-invaded countries are included. Further chapters are dedicated to the utilization of GAS as food and as natural paddy weeders. Some information on the biorational approach to the pest's management and control is also provided. The book has practical applications, including various ecological and sustainable options for dealing with GAS invasions. It is a manual for field researchers and extension workers, and a reference book for students of biological sciences, as well as industry workers, museums and libraries where exhaustive information on this topic is needed.

[1]Joshi, R.C. & Sebastian, L.S. (2006) *Global advances in the ecology and management of golden apple snails*. Philippine Rice Research Institute (PhilRice), Manila.

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How to Import Biocontrol Agents to Canada

A new Canadian guide, prepared for the Agriculture and Agri-Food Canada (AAFC) Biological Control Working Group, available online, provides information for petitioners, reviewers of petitions and interested Canadian citizens on the requirements for obtaining regulatory permission for importation and release of arthropod biocontrol agents in Canada, with information presented separately for agents against weed and arthropod targets pests where protocols for testing and petitioning differ. The guide also outlines the process involved in preparing a petition of standardized format, and how the actual permit for importation is obtained after an agent has been approved for release. For reviewers, it outlines what information should be provided by petitioners to allow for a scientifically sound assessment of the safety of a candidate agent.

De Clerck-Floate, R.A., Mason, P.G., Parker, D.J., Gillespie, D.R., Broadbent, A.B. & Boivin, G. (2006) *Guide for the importation and release of arthropod biological control agents in Canada.*[Available in English and French]

Web:
www.agr.gc.ca/env/pest/index_e.php?page=arthro

Conference Reports

Have you held or attended a meeting that you want other biocontrol workers to know about? Send us a report and we will include it here.

Chromolaena and Mikania Workshop

The Seventh International Workshop on Biological Control and Management of *Chromolaena odorata* and *Mikania micrantha* was held in Taiwan on 12–15 September 2006.

International Workshops on Biological Control and Management of *Chromolaena odorata* have been held under the auspices of the IOBC (International Organization for Biological Control of Noxious Animals and Plants) since 1988, at 3–4 yearly intervals. These workshops were initiated to facilitate the exchange of expertise and information and to coordinate research on an invasive alien plant species which is largely a problem in tropical and subtropical developing countries with limited resources. Over the years it has been attended by representatives from many countries affected by chromolaena in Africa, Asia and Oceania and has proved an effective forum.

One of the recommendations emanating from the Sixth International Workshop on Biological Control and Management of Chromolaena, held in Australia in 2003, was that the focus of the workshop should be expanded to include other invasive species within the same tribe of Asteraceae (Eupatorieae) as chromolaena. This recommendation was based on (i) the substantial number of such species, (ii) the fact that many have similar biology to chromolaena and are often attacked by similar natural enemies, (iii) the fact that all originate in the Neotropics and many affect developing countries, and (iv) the realization that chromolaena is coming under increasing control and therefore the need for workshops exclusively focusing on this species is declining. The recommendation was realized with the inclusion in this seventh workshop of *Mikania micrantha*, a climber which is a serious weed in tropical Asia and Oceania.

Both *C. odorata* and *M. micrantha* are problematic in southern Taiwan. The National Pingtung University of Science and Technology (NPUST) recently initiated a biocontrol programme against chromolaena, importing and conducting host-range tests on the stem-galling fly *Cecidochares connexa* and the defoliating moth *Pareuchaetes pseudoinsulata*. NPUST, with generous sponsorship from the Forestry Bureau of the Taiwanese Council of Agriculture, thus offered to host the seventh workshop, which was attended by about 20 international participants, from Australia, Guam (USA), India, Indonesia, Papua New Guinea, Saipan (Commonwealth of Northern Mariana Islands), Secretariat of the Pacific Community – SPC (Fiji), South Africa, Timor-Leste (East Timor) and the UK, and by about 30 local participants.

The themes of the sessions were ‘sustainable control, importation of natural enemies, introduction and establishment, classical biological control of weeds, host specificity testing and influence of environmental factors’. Some of the most significant developments highlighted at the workshop were the continued and increasing success of *Cecidochares connexa* in controlling *Chromolaena odorata* in the higher rainfall areas of Southeast Asia; its establishment in India; the increasing populations of the acraeid butterfly *Actinote thalia pyrrha*, which feeds on *C. odorata*, *M. micrantha* and *Austroeupatorium inulaefolium* in Sumatra; the establishment of the damaging rust fungus *Puccinia spegazzinii* on *M. micrantha* in India; and the establishment of *Pareuchaetes insulata* on *C. odorata* in South Africa.

At the end the following recommendations were made:

1. Governments of all countries affected by chromolaena are encouraged to consider the introduction of *Cecidochares connexa.*

2. Governments of all countries affected by chromolaena and mikania are encouraged to send representatives to the next workshop.

3. Regional organizations e.g. SPC and countries affected should produce public awareness material on chromolaena for identification and containment and control measures.

4. Countries should increase awareness of, and promote, biological control of weeds and its benefits.

A record of proceedings of the workshop is due to be published soon, and will be available online:
www.ehs.cdu.edu.au/chromolaena/siamhome.html

By: G.V.P. Reddy & C. Zachariades, October 2006.

REBECA Considers Classical Biocontrol using Microbials

Regulation 91/414 is an EU (European Union) regulation originally designed to license chemical plant protection agents. This regulation is also used to license plant protection products manufactured from microbial and macrobial agents. REBECA (Regulation of Biological Control Agents) is an EU funded project looking at proposed amendments to the current regulation (91/414) on macrobial and microbial biological control agents for use within the European Union (see *BNI* 27(2) 33N–34N & 44N–45N; www.pestscience.com/PDF/BNI_JuneGN.pdf).

The latest REBECA workshop, on current risk assessment and regulation practice, was held on 18–22 September 2006. It was attended by 115 participants mostly from Europe with representatives from the USA, Canada, Australia and New Zealand and these represented science (or academia), industry, environment and regulation – at times this proved to be a very interesting mix of opinions and opposing viewpoints (sometimes vehement).

Reports from the following were presented:

- Risk assessment workshops from Innsbruck, Brussels and Wageningen
- Results from stakeholder meetings (industry and regulation)
- Summary of the 'Obstacles and Proposals' questionnaire
- Presentations from invited speakers on each of the biological control agent types (bacteria; fungi; viruses; botanicals; semiochemicals; macrobials)

The reports and presentations will appear on the REBECA website (www.rebeca-net.de) in due course.

Breakout meetings for each of the subject areas took place on Wednesday afternoon and Thursday morning. This contributor attended the fungal group, which proved to be the largest group by far with just under 40 participants. Most of the discussions revolved around fungi as insecticides, soil amendments, gene extracts and metabolites. The topic of fungi used as classical biological control agents (CBCAs) for invasive alien weeds (IAWs) did not feature in the consciousness of those present. Regulation 91/414 does not take into account CBCAs as Europe does not have a history of using this type of control – unlike countries such as Australia, New Zealand, USA and Canada which have specific legislation to cover their use. The potential for using CBCAs in EU countries will be lost if 91/414 applies to their release as the cost of such an undertaking would be prohibitive. So, when just before the close of business on Wednesday, the group facilitator (Hermann Strasser) asked for specific topics for the following morning, this contributor seized the opportunity to fungal CBCAs on the map with REBECA, and the following morning, gave a presentation on how fungi (and arthropods) are used as an effective tool (in terms of efficacy and cost effectiveness) to control IAWs in Australia, New Zealand, South Africa, USA and Canada. Mark Goettel (Agriculture Canada) commented on CABI Europe – Switzerland's long history of involvement in Canadian classical biological control projects, which has involved surveying, screening and supplying macrobial CBCAs to Canada. REBECA is planning to take forward a recommendation to the EU that CBCAs should be exempt from 91/414 and should be regulated under other legislation (e.g. environment or plant health).

By: Barbara J. Ritchie, CABI Europe – UK.

Neobiota in Vienna

'Neobiota – From Ecology to Conservation', the Fourth European Conference on Biological Invasions, took place in Vienna (Austria) from 27–29 September 2006. The conference, held at the Old University Campus in Vienna, was the fourth in a series of biennial meetings addressing the issue of biological invasions by alien species in Europe. Since the first meeting held in Berlin in 2000, the number of participants has grown steadily with over 350 delegates from around 43 countries registered at this year's conference. Representation from countries outside Europe included the USA, Canada and New Zealand as well as Israel, Iran, India, Korea and Japan. The rise in the number of delegates reflects the growing European concern about invasive alien species (IAS). The Neobiota meetings provide the ideal platform for scientists, practitioners and stakeholders to exchange latest results of scientific research as well as to discuss the implementation of IAS strategies in a pan-European context beyond national borders.

The emphasis of this conference, which was organized jointly by the Austrian Federal Environment Agency and the German Federal Agency for Nature Conservation, was on the implementation of IAS strategies, based on sound scientific knowledge focusing on aspects of species ecology through to the conservation of biodiversity in Europe. During the 3-day meeting all fields of biological invasions covering pathogens, plants, fungi and animals as invasive organisms in marine, freshwater and terrestrial habitats were addressed with invited keynote speeches as well as oral and poster presentations.

On registering for the meeting on Wednesday afternoon, each participants was presented with a small jar of Japanese knotweed (*Fallopia japonica*) jam. Tasting surprisingly nice, this might offer one option to take advantage of the growing infestations of this number one invasive species in Europe which originates from volcanic mountain slopes in Japan (but not one likely to be recommended by many biocontrol scientists). The meeting was opened with a welcoming speech given by Wolfgang Rabitsch from the Austrian Federal Environment Agency, followed by an invited keynote lecture on 'High and low tech success stories to combat IAS' presented by Professor Daniel Simberloff from the University of Tennessee, USA, which stimulated much discussion. The schedule for the two subsequent days was very tight and fully packed with 42 oral and 206 poster presentations, as the actual number of delegates had exceeded all expectations. Poster presentations were held during coffee and lunch breaks giving opportunities for discussion amongst delegates as well as opportunities to renew old and establish new contacts.

Efforts to promote weed biocontrol in previous meetings on IAS in Europe are beginning to bear fruit. The introduction of specific natural enemies to control invasive plants is starting to be considered alongside other potential management options, as problems created by invasive weeds become more and more pressing. The Neobiota conference provided an opportunity for biocontrol scientists working on various invasive species from all taxa to meet formally and informally to exchange ideas and make plans. In this regard, at the main meeting discussion partly focused on the potential for biocontrol of the invasive exotic plants, notably *Fallopia* spp. and *Ambrosia artemisiifolia* (ragweed). There was a good deal of interest in the progress of the biological control project on *F. japonica* (Japanese knotweed) currently underway at CABI Europe – UK, and the outcome may well affect the view of many decision makers with respect to investment in this strategy. Other weed species discussed in relation to biological control were Himalayan balsam (*Impatiens glandulifera*) and *Rosa rugosa*.

An *Ambrosia* workshop was held before the main meeting, organized by the Austrian Agency for Health and Food Safety (AGES) and the German Federal Biological Research Centre for Agriculture and Forestry (BBA) because of the high level of interest in this invasive weed. The publication of recommendations for the prevention and control of *Ambrosia* with special reference to the need for biological control is planned. The recommendations have been prepared by representatives of AGES, BBA, CABI and EPPO (the European and Mediterranean Plant Protection Organization). A further meeting addressing the issue of *A. artemisiifolia* invasion and its control will be held at the BBA in Braunschweig in December 2006.

An informal meeting was also convened on *Harmonia axyridis*, the harlequin ladybird introduced as a biological control agent, but which is presently invading Europe, with participants discussing how best to harmonize activities in the various affected countries.

The Neobiota meetings are also becoming hosts to major projects, who take advantage of this gathering of invasive species specialists. The bi-annual meeting of the biological invasions module of the ALARM (Assessing large-scale risks to biodiversity using tested methods) project preceded the conference. This large integrated European Union (EU) project now includes more than 60 teams. Biological invasions is one of the four categories of 'environmental risks' included in ALARM. Another major project to take advantage of the gathering was the EU project DAISIE (Delivering alien invasive species inventories for Europe), whose participants met over 2 days during the conference. The main goals of the project are to make inventories of alien species in Europe, with fact sheets and distribution maps.

The Neobiota conferences have become one of the most important meetings series for invasive species in Europe. The level of attendance and diversity of participating groups make it a key place at which to promote biological control as a sustainable approach for IAS management in Europe.

Apart from the scientific contributions, one other highlight of the meeting was the conference dinner held at the Natural History Museum in the centre of Vienna, a truly impressive building providing an amazing setting for such an event. This was only topped by the opportunity to have a small guided tour which ended on the roof of the building giving the view over the city by night.

The Fifth Neobiota Conference will be held in Prague (Czech Republic) in 2008 and is likely to attract an even higher number of delegates given the increasing importance of IAS in Europe.

By: Marion Seier, Esther Gerber & Marc Kenis (CABI Europe).