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General News

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Indirect Biological Control for Yellow Crazy Ants on Christmas Island

Indirect biological control of the yellow crazy ant (*Anoplolepis gracilipes*), an exotic ant species threatening endemic biodiversity on Christmas Island, could be tackled by introducing a parasitoid of a scale insect with which it has a mutualistic association. The yellow lac scale (*Tachardina aurantiaca*) is also exotic and is damaging native and introduced fruit trees, but it is its role in the yellow crazy ant invasion that makes it a target for classical biological control. In a joint programme, researchers from La Trobe University in Melbourne, Australia and their colleagues in Parks Australia are gearing up to import a parasitoid they hope will be a key player in the indirect control of yellow crazy ants on Christmas Island.

Classical biological control has great potential for broad-scale, sustainable management of some invasive species and their impacts in remote natural areas where other management strategies are impracticable. Christmas Island is an Australian territory of some 135 km^2 in the Indian Ocean, and over 60% of this area is a national park managed by Parks Australia. Much of the natural ecosystem, which includes large areas of rainforest, was considered intact until the yellow crazy ant became invasive. The island is home to a large endemic fauna and flora. Most famously, the terrestrial fauna is dominated by a unique diversity and abundance of endemic land crabs. The red land crab (*Gecarcoidea natalis*) is the dominant consumer of the forest floor and a keystone species with a major role in determining the structure and function of the rainforest.

Yellow crazy ant has been present on Christmas Island for at least 70 years, for a long time at low densities and with little impact. This changed after multi-queen 'supercolonies' began to form. They occurred in increasing numbers during the 1990s in close to 25% of the island's rainforest, and to date have probably occupied around a third of it. Supercolonies extend over areas as large as 7.5 km^2 and densities can exceed 1000 ants per square metre, foraging night and day on the ground and in the canopy. As scavenging predators, they attack a wide variety of small invertebrates and larger animals including endemic land crabs, reptiles, birds and mammals, which the territorial ants also perceive as intruders. An individual ant deploys a tiny amount of formic acid that overcomes only small prey, but the numbers involved in an attack by a supercolony can overwhelm large animals. Although many adverse impacts on the island's endemic and endangered biodiversity have been recorded, it was the impact on land crabs that really raised alarm. Where ants occur at supercolony densities they devastate red land crab populations, but these crabs also migrate to and from the sea to breed, and many traditional migration routes pass through supercolony areas where migrating red land crabs were attacked, leaving the areas they lived in depleted. This 'ghosting effect' meant rainforest with and without supercolonies suffered significant changes in habitat structure, plant recruitment dynamics, litter dynamics and resource availability as a result of the loss of the keystone species. A knock-on effect of the removal of red land crab predation also allowed populations of exotic species normally kept in check to escape – a phenomenon termed 'invasional meltdown' – including the introduced giant African land snail (*Achatina fulica*), which has established at high densities in rainforest because it can coexist with the yellow crazy ant.

Yellow crazy ant invasion and supercolony formation was listed in 2005 as a Threatening Process under the Environment Protection and Biodiversity Conservation Act 1999. The invasion has been managed so far by surveillance, monitoring, and baiting with fipronil. But this can only be a reactive programme, and baiting only where the density of the invasive ants means that non-target effects will be minimal, so incipient supercolonies cannot be targeted. The cost of continuing the programme long-term is under scrutiny as well as the resources it diverts from other conservation efforts. In addition, the island has two Ramsar wetlands where fipronil cannot be used in the core areas owing to its aquatic toxicity. Five years ago, Parks Australia teamed up with La Trobe University to look for a sustainable solution.

This will be only the second initiative to implement classical biological control against an invasive ant, and a novel approach was devised for Christmas Island. Ants rely for carbohydrates on honeydew from Hemiptera with which they have a mutualistic association. In supercolony areas, columns of ants stream continuously up and down tree trunks as they forage intensively for this resource, and research by La Trobe scientists found that this was key to supercolony formation in that the dynamics and behaviour of the ants depended on the level of carbohydrate supply, and, crucially, that blocking yellow crazy ants' access to scale insects in a large field experiment caused a five-fold decline in ant activity in four weeks. There are no native scale insects on Christmas Island, although there are a number of introduced species. Of five such species – four soft scales (coccids) and the yellow lac scale (*Tachardina aurantiaca*; a kerriid) – commonly found in abundance in supercolony areas, they estimated that *T. aurantiaca* was the most significant, supplying 46–87% of honeydew needs and concluded that ant populations would be severely affected if populations of this insect could be reduced.

Tachardina aurantiaca is widespread but locally rare within its home range in Southeast Asia, suggesting effective population control by natural enemies. In 2007 and 2008, initial foreign exploration

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for natural enemies of *T. aurantiaca* in Southeast Asia identified an encyrtid parasitoid, *Tachardiaephagus somervillei*, as a potentially effective biological control agent for use against *Tachardina aurantiaca* on Christmas Island. Species in this parasitoid genus in India and Southeast Asia attack the lac scale of commerce (*Kerria lacca*), a close relative of *T. aurantiaca*, and no *Tachardiaephagus* species is known to attack scale insects outside of the Kerriidae. *Tachardiaephagus somervillei* is especially promising because it produces multiple generations per year, exhibits superparasitism, and can sustain high rates of parasitism on *Tachardina aurantiaca* at sites across Southeast Asia, even in the presence of tending ants, including the yellow crazy ant.

Assessment of the potential for non-target effects from introducing *Tachardiaephagus somervillei* was based on analysis of historical records, and some novel analyses using John Noyes' Universal Chalcidoidea Database. Host-specificity testing was conducted in the area of origin in Malaysia, using a protocol agreed upon with international experts. Since there are no non-target species of concern present on Christmas Island, the choice of eight test species more and less closely related to the target species was based on the phylogenetic centrifugal approach. Four coccids (including three exotic but present on Christmas Island), one diaspidid and three pseudococcids were assessed in replicated no-choice field tests; tests included both negative and positive controls to assess test insect background mortality and quality, respectively. No parasitoids emerged from any test species and these results, backed up by historical and database evidence, show that *T. somervillei* has a narrow host range restricted to the Kerriidae. One other (non-native) Kerriidae, *Paratachardina pseudolobata*, is also found on Christmas Island, but that is also a pest so impact on it would be good rather than bad. As well as showing host specificity, the scientists investigated and demonstrated safety of introducing *T. somervillei* for a range of other issues, for example: competition with native parasitoids is unlikely; hyperparasitoids can be effectively screened out before import; threatened or migratory birds do not rely on the large lac insect populations as important prey; coccids have a different feeding niche and will not expand to fill the gap left by falling lac insect populations – and moreover, planned re-distribution of two well-known, non-native coccid parasitoids already present on Christmas Island should help suppress their populations and the ant's honeydew supply further.

Applications summarizing the research results and conclusions and seeking permission to import the parasitoid to Christmas Island are being evaluated under two stringent regulatory processes governed by separate pieces of Australian legislation. These are managed by the Department of the Environment and the Department of Agriculture. The basis of both applications is that the risks of importing the agent are considered minimal, while the likely consequences of failing to manage supercolonies of the yellow crazy ant are very large. The applications argue that following the release, population build-up and spread of *T. somervillei* on Christmas Island, both its abundance and that of its host, *Tachardina aurantiaca*, should follow classic parasitoid–host dynamics, and both should decline to low population densities similar to the situation observed in the native distribution of both organisms in Southeast Asia. All the available evidence indicates that yellow crazy ants will not be able to sustain high-density supercolonies in the near-absence of their mutualistic scale insects. The draft risk analysis produced by the Department of Agriculture, which went out for public consultation in July 2015, has proposed that the release should be permitted.

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Endemic Snails Return to Tahiti

The prospect of releasing more snails in French Polynesia might well strike horror in the hearts of both biological control practitioners and conservationists. However, captive-bred *Partula* spp. snails hand-carried from London Zoo to Tahiti in July are the vanguard in attempts to safeguard species that were decimated or made extinct in the wild by a disastrous attempt at biological control.

The giant African land snail (*Achatina fulica*) was introduced to Tahiti in 1967 as a food source but became an agricultural and garden pest there, and on other islands in French Polynesia to which it spread. The snail was already a pest in other Pacific islands including Hawaii, where a voracious, generalist snail predator, the rosy wolf snail (*Euglandina rosea*), had been introduced from Florida in 1955 to try and control it. Faced with the demand to 'do something' (*A. fulica* numbers were so high in Moorea that it invaded houses; two wheelbarrows of snails were reportedly removed from the walls of a single house), the decision was taken by the local government authorities in French Polynesia to introduce *E. rosea*. Despite warnings from snail experts that it would be ecologically catastrophic, *E. rosea* was released without adequate field trials in Tahiti in 1974, Moorea in 1977, and other French Polynesian islands in the 1980s–90s.

French Polynesia had a unique diversity of tree snails (Partulidae). The family is endemic to the 'high islands' of Oceania (i.e. those with mountains high enough to generate their own rain to support rainforest formation) and half of all species were found in the Society Islands group in French Polynesia. They were important to the islands' culture and economy – for shell decorations and jewellery – and also as the subject of a century's research as an example of island evolutionary radiation. As snail experts had predicted, the introduced predator fed preferentially on the small partulid snails instead of the much larger target. The progressive extinction of *Partula* spp. as *Euglandina rosea* spread across Moorea was documented by the scientists studying them. Later surveys in other Society Islands revealed similar devastation. Within a decade, all but five of the 61 endemic Society Island *Partula* species became extinct in the wild.

As the dire reality became apparent, specimens were collected to establish *ex-situ* breeding colonies, initially in the research laboratories but zoos around the world quickly became involved. Under a collaborative programme coordinated by London Zoo, *ex-situ* breeding was expanded, further surveys conducted and plans for long-term conservation and management developed. Currently 15 species (of which 11 are extinct in the wild, three are critically endangered and one is listed as vulnerable) are being cultured in 15 institutions in six countries. In 2003 the French Polynesian government made funds available to maintain an *in-situ* biologist and to develop further the collaboration with the zoo community in order to realise the re-establishment objectives of the programme.

The captive-bred snails taken to Tahiti are from three endemic Tahitian *Partula* species and have been released into a *Euglandina*-proof reserve constructed for the purpose. The target species *Partula affinis*, known in the wild from only one small surviving population on the peninsula of Tahiti-iti, has been released within its natural range. *Partula hyalina*, possibly the best-surviving of Tahiti's *Partula* spp. in the wild, has been introduced as a control in smaller numbers. Surveys spanning two decades have shown the third species, *Partula nodosa*, to be extinct in the wild. Breeding of this species began in 1989 in Detroit Zoo, which for a time held the only living specimens of the snail. Two types of re-introduction are being tried for *P. nodosa*, which has a different distribution to the other two species: 250 have been released as another control into the reserve, which is outside its native range, while 250 have been released directly into trees in the valley from which all the breeding stock of that species in the conservation programme originates – and where currently there are no *E. rosea*.

The *Euglandina*-proof reserve has been established on government-maintained land in the Te Faaiti Natural Park (the only one on Tahiti) as part of wider habitat restoration in the valley. The reserve, which at only 12 m by 9 m is the world's smallest nature reserve, was constructed in 2012, drawing on experience gained about design and snail survivorship from a previous reserve on Moorea which, however, suffered from monitoring and maintenance issues. One important lesson was that reserves are costly and labour-intensive to maintain. The long-term strategy now, if the trial with *Partula nodosa* is successful, is to release imported *Partula* snails directly into trees, the dry trunks of which may act as some impediment to *E. rosea*. If extra protection is needed, it would be much cheaper and less complicated to protect individual trees to safeguard the snails than to construct and maintain predator-proof reserves.

The overall objective is to return representatives of all the species extinct in the wild but surviving in the international breeding programme back onto their original islands of Tahiti, Moorea, Raiatea and Huahine over the coming years, and to retain a health breeding stock for replenishment and in case of disaster.

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Further Information

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Pathogens against Lantana: New Zealand Releases New Agent

The world's first release of lantana blister rust (*Puccinia lantanae*) against *Lantana camara* has taken place in New Zealand's North Island as part of a preemptive strike. A second rust pathogen, the lantana leaf rust (*Prospodium tuberculatum*), previously released in Australia, was also released as part of the initiative. Although established in the wild in New Zealand for over a century, *L. camara* only emerged as a serious weed in an area of North Island during the 1980s, and it is not yet a serious weed elsewhere. Landcare Research scientists hope that biological control will contain the problem.

While many countries have conducted biological control programmes against *L. camara* that date back more than a century, the potential of host-specific plant pathogens is giving renewed hope for containing the many forms of this escaped ornamental, which thrive in a variety of habitats and climates. In all, 43 biocontrol agents have been released in 32 countries, but those that have established have had limited impact on lantana. Agents have a more restricted climatic tolerance than lantana, and may not attack all its forms. In addition, lantana has the ability to survive long periods of defoliation as a result of drought or winter.

On advice from Michael Day (Queensland Department of Agriculture and Fisheries – QDAF), Landcare Research discounted insects agents released in Australia as not likely to thrive in New Zealand's climate and instead considered the pathogens. One, *Prospodium tuberculatum*, was first released in Australia by QDAF in 2001. The agent has established widely there and glasshouse trials indicate that it has a chronic impact on lantana. The rust causes seasonal defoliation of only the pink-flowering form in Australia. New Zealand has just two invasive forms of lantana, the pink-flowered one and an orange-flowered form. Quarantine glasshouse tests in Australia by QDAF found that the rust attacks both forms occurring in New Zealand.

The second agent, *Puccinia lantanae* is widely distributed in the home range of *L. camara* in the Neotropics, but a particularly damaging isolate from Peru was identified by CABI scientists and tested against non-target host plants for Australia, New Zealand and South Africa.

The logic for releasing the two pathogens in New Zealand is that they have been shown to co-exist on lantana but are expected to complement one another owing to different climatic requirements. *Prospodium tuberculatum* is predominantly a leaf pathogen, causing leaf death and defoliation. It is subtropical and expected to be less dependent on high humidity and/or high rainfall. With a wide geographical and altitudinal distribution in South America, it is anticipated to be able to adapt to a range of subtropical climates so should thrive in the Bay of Plenty area of the current *L. camara* infestation and have the potentially wider distribution in future. The Peruvian isolate of *Puccinia lantanae* is a damaging pathogen of leaves, petioles and stems, and causes systemic infections that lead to stem dieback. From its distribution in South America, it is a tropical species that prefers, and may be restricted to, warmer wet areas, and thus very suitable for attacking infestations in the tropical Far North.

First screening work on *P. lantanae* for QDAF, completed in 2010, raised concern that the rust caused mild infection symptoms on varieties of *Verbena officinalis*, a purported Australian native species in the same family as *L. camara*, the Verbenaceae. This delayed a decision on whether the rust should be released in Australia, and what further work would be needed to help in this process. A similar obstacle arose for South Africa, with two native *Phyla* species also in the Verbenaceae showing weak symptoms of susceptibility.

The outcome for New Zealand was more positive, with no plants on its non-target list infected. An application to release the rust was made to the Environmental Protection Authority in 2011 by Northland Regional Council, and permission to release was granted in 2012. In early 2013, CABI sent a shipment of *Puccinia lantanae* which was imported into a newly constructed plant pathogen quarantine containment facility at Landcare Research in Auckland. Meanwhile, Michael Day sent a culture of *Prospodium tuberculatum*. Initial technical hitches were overcome (and some repeat shipments made) and both pathogens established in culture for mass-rearing, which allowed the first releases. Both require warmth and moisture for infection, so (austral) autumn 2015 was a good time to start, with further releases planned for the spring.

For Australia, CABI is continuing with screening work for *Puccinia lantanae* by undertaking host-range screening of an additional four species from the families Acanthaceae and Verbenaceae plus a further assessment of *V. officinalis* var. *gaudichaudii* with variable doses of the rust.

In South Africa, where a leaf-spot fungus, *Passalora lantanae* (=*Mycovellosiella lantanae* var. *lantanae*), failed to establish after promising early signs [*BNI* 31(3), 21–22] they are hoping the new agent will be more successful. CABI has completed screening for *Puccinia lantanae* and an application to release it is being prepared by ARC-PPRI Weeds Research Division.

Main source: Hayes, L. (2015) Lantana rust releases to begin. *What's New in Biological Control of Weeds?* Issue 71, p. 5. Landcare Research New Zealand Ltd 2015.

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From Past ISBCWs to the Future of Weed Biological Control

The authors of a unique paper in *Biological Control*[1] analyse attendance at the 14 International Symposia on Biological Control of Weeds (ISBCW), from 1969 to 2014, and relate their findings to the fortunes of weed biological control (WBC) over the same time span. By identifying repeat attendees, authors Moran and Hoffmann calculate that only 1144 individuals have ever attended a symposium, and 75% have come from the 'big five' implementing nations of Australia, Canada, New Zealand, South Africa and the USA; the remaining 25% include a substantial number from organizations in non-implementing nations that conduct research for the 'big five', e.g. CABI. Far from seeing a trend towards growth that might be expected for a discipline with a proven record of success and safety, they found that numbers of participants have plateaued and are even decreasing.

By an astoundingly painstaking process, they identified how many participants were WBC practitioners ('appropriately qualified professionals who usually would have published specifically in the field of WBC, and who would classify themselves principally as 'weed biocontrollers') and from this, and by consultation with the authors of the new 'Biological Control of Weeds' world catalogue, inferred the size of the sector worldwide. They estimate that WBC has been, and remains, in the hands of as few as 450, at most 550, WBC practitioners, with risks to the future of the discipline inherent to such a small size. Moreover, they identify a 'tipping point' in the late 1990s after which attendances and by extension WBC as a whole began to contract. This mirrors observations that, with limited exceptions, the rate of WBC agent introductions – a proxy for progress – fell worldwide. Looking at recent meetings, Moran and Hoffmann found a decline in 'new recruits', suggesting a dearth of the young scientists necessary for the future of WBC. They discuss a number of factors contributing to the gloomy picture, but assign most blame to 'protracted debate on non-target effects' for creating a risk-averse environment. The question is, given the long history, success and safety record of WBC, why were scientists reporting non-target effects in a very few cases not dismissed as doomsayers?

Summarizing changes in global attitudes over the last quarter-century, in the latter part of the twentieth century growing recognition of the importance of conserving the natural world culminated in the Convention on Biological Diversity (CBD), which was signed by 150 government leaders at the Earth Summit in Rio de Janeiro in 1992 (almost all countries are now Parties, although not the USA). The CBD came into force in 1993 as a legally binding document placing obligations on Parties to address conservation of biodiversity, sustainable use of its components, and fair and equitable sharing of benefits arising from utilization of genetic resources. This represented a key shift from longstanding preoccupation with species of agricultural/anthropomorphic importance and, for WBC, the need for more emphasis on potential impacts on native plant species. At the same time, Principle 15 of the Rio Declaration emphasized the precautionary approach to protect the environment, which came to have a massive impact on decision making. Many countries were unsure what to do, struggled with the need to align national legislation with requirements of the CBD, and stalled. In addition, two decades of discussions ensued as countries grappled to understand and agree what access and benefit sharing meant, with the relevant Nagoya Protocol to the CBD not taking effect until 2014. In the atmosphere of uncertainty, some countries restricted access to unexplored biological resources, putting research on biodiversity, which by default included exploration for and export of new potential biocontrol agents, on hold.

Over this same period, eliminating human poverty became an overriding global concern and at the core of the international sustainable development agenda. The CBD's requirement to protect biodiversity was tempered with the recognition that conservation of biodiversity could not be achieved without including people. Conservation organizations repositioned themselves. The commitment to mitigating poverty was enshrined in the Millennium Development Goals in 2000 and later the Sustainable Development Goals (SDGs). Recognized in the SDGs, also, is a third major event: recognition of climate change and the urgent need for action to mitigate its impacts.

At first sight, the CBD should have had a positive impact on WBC. Article 8(h) requires Parties to deal with invasive alien species as the second greatest threat to biodiversity and greatest threat on islands, which presented an opportunity for CBC to be implemented more widely. Classical biological control is a tried-and-tested approach for controlling invasive alien species, especially in the 'big five' countries, and there was guidance for countries with no experience (the 'Code of Conduct' – ISPM 3).[2] Following the 1996 Norway/UN Conference on Alien Species, convened to identify how to help countries implement Article 8(h), the Global Invasive Species Programme was formed and developed guidance (the GISP 'Toolkit')[3] that emphasized classical biological control as a management tool. WBC was well placed: testing a proposed WBC agent for impact on non-target organisms had always been a larger issue than for invertebrate biocontrol agents because of the need to protect crop plant species, and also because of the prevailing view that plants are good and, pollinators apart, insects on the whole bad. As Moran and Hoffmann discuss, WBC protocols for host-specificity testing were well established. During the protracted discussions on ABS, the International Organization for Biological Control formed the Global Commission on Access and Benefit Sharing[4] to provide advice and lobby for biological control to be given appropriate consideration and, since the Nagoya Protocol came into force, is developing relevant guidance. Moran and Hoffmann note that strong economic arguments for WBC have been made in Australia and South Africa. Biological control scientists have also been involved in assessing the likely impact of climate change on biocontrol agents as part of wider studies on agriculture and food security.[5]

Management of invasive alien weeds in natural/protected areas, required under the CBD, is amenable to WBC, and sometimes the only acceptable or sustainable approach over large natural areas. Although agricultural (especially pasture/rangeland) weeds figure most in the history of WBC because of longstanding focus on these sectors, notable successes have been achieved against environmental weeds. However, there is an uneasy relationship between conservationists, who are reluctant to consider deliberate introductions of exotic organisms, and classical biological control practitioners. Nevertheless, a Biological Control for Nature conference in Massachusetts in 2010, which showcased biological control projects in natural areas, indicated that it was a small but increasingly active field, and culminated in a multi-author review paper.[6]

So what went wrong? It was not an inability of the WBC community to adapt its methods to address the rare cases of non-target effects. Moran and Hoffmann say 'astute and observational science' demonstrating these served to heighten awareness among WBC practitioners of the need for 'more rigorous and sophisticated host-specificity testing' both to improve the predictability of success and to further minimize risks. The confounding factor was that a risk-averse culture had taken hold, an issue addressed in a 2003 review by Sheppard and coauthors[7] cited by Moran and Hoffmann.

Two cases of significant non-target impacts arose, as Moran and Hoffmann describe, from earlier introductions made following due processes of the time under prevailing values. The South American moth *Cactoblastis cactorum* spread to North America from the Caribbean, where it had been introduced in the 1950s to control cactus, and was detected on *Opuntia* species in Florida in 1989. The European weevil *Rhinocyllus conicus* was introduced to North America in the 1960s to control a Eurasian thistle, and impacts on a non-target native thistle were reported in 1997. These energized a debate about non-target effects in a world now more sensitized to environmental issues – Moran and Hoffmann identify a 'burgeoning number of publications' on the topic in the late 1990s. In this setting, academic debate about non-target effects on native flora spread from scientists to push buttons for policy makers and help fuel the development of a risk-averse attitude to WBC, culminating in what Moran and Hoffmann describe as 'an exaggeratedly negative view of WBC' and 'harshly, risk-averse political and regulatory environments.' This was because the debate moved on from the spread of *C. cactorum* and non-target effects of *R. conicus*; those are proven. What created uncertainty for decision makers was that while WBC practitioners say that these are extremely rare cases, their challengers say that there is no evidence for most systems because monitoring is inadequate, and unrecorded non-target effects could be and probably are widespread. This is frustrating for WBC practitioners not least because they have long called for post-release monitoring but until funders' objectives started to include showing that money had been well-spent, funds for post-release studies were rarely available. Nevertheless, the WBC community is adamant that their testing protocols are sound and that non-target effects are extremely rare while the benefits of WBC are enormous; even in systems where non-target effects are shown, the absence of biological control and continued impacts of the target weed would have been potentially more damaging to non-target species than the effects of the introduced agent. It is interesting to note that in Europe where WBC is considered novel, the first releases that took place required extensive, funded non-target impact monitoring plans as part of the release licence.

The 1990s was also the era of the introduction of the first genetically modified crops – a different kind of 'alien'. The debate surrounding these, together with the separate and increasing awareness of invasive alien species, in a risk-averse world had the effect of making all introduced species 'bad', and that came to include classical biological control. Detractors pointed out that a classical biocontrol agent behaves *like* an invasive, losing the critical distinction that it has been carefully selected to do 'good' not 'harm', and an invasive alien species is by definition one that does harm (a point that eludes some critics who question the concept of invasive species).

As Moran and Hoffmann's analysis indicates, WBC practitioners vary across a wide range, from an experienced practitioner implementing WBC under a government-funded programme in a country with more than a century's history of the approach, to someone in a country with no such history and seeking to introduce WBC agents for the first time with the aid of donor funding. The events described above affected practitioners differently. In the former case, national decision-making bodies often imposed additional regulatory steps that led WBC projects to founder under the weight of additional testing, or the risk-assessment machinery itself seized up. In the latter, there was no experience to inform decision-making, and governments were mired in uncertainty; in addition, global agenda changes meant donor agencies were focusing on livelihoods and WBC was more likely to be part of a larger livelihoods programme rather than a standalone project. Cross-disciplinary interactions could be very beneficial, but prior socioeconomic data were required to back up applications for funding, along with indicators for demonstrating positive impacts on livelihoods.

The Sheppard *et al.* 2003 review provided a detailed comparison and discussion of established risk analysis procedures, with the ultimate aim of helping countries to develop a system of assessment that was effective in protecting biodiversity without being so onerous and protracted that WBC grinds to a halt. They noted at that time that 'the benefits of biological control remain poorly understood by the public, allowing the risks to attain disproportionate attention.' Moran and Hoffmann argue that recent pivotal publications on WBC have surely confirmed the safety record and environmental soundness of the discipline beyond doubt, and that this message needs to be said louder than the voices of WBC's detractors.

Developments within the CBD arena may help: a Decision at the Conference of the Parties to the CBD in the Republic of Korea in October 2014 (COP 12) asked for information to be compiled on 'experiences in the use of biological control agents against invasive alien species, in particular the release in the wild of alien species for this purpose, including positive and negative cases and cases of the application of appropriate risk assessment' for consideration by the CBD's Subsidiary Body on Scientific, Technical and Technological Advice before COP 13 in 2016.

There are other hopeful signs. Throughout the debacle, as Moran and Hoffmann note, New Zealand has gone against the tide in continuing to have a flourishing WBC sector and has sought to share its experiences in meeting contemporary regulatory requirements. In South Africa a protracted stalemate caused by risk-averse attitudes and restrictive practices was lifted in 2014 when cooperation between two government departments and the country's biodiversity institute led to a backlog of applications being reviewed and a host of new releases followed. Countries new to WBC are also finding a way forward: Ethiopia made its first WBC release in 2014 against *Parthenium* under a project with US and South African partners that began in 2005 and included capacity building as a key component. Moran and Hoffmann cite Europe, also new to implementing WBC, as a beacon of hope, with the first releases of WBC agents in the UK in recent years (and Portugal potentially following suit following a recent European Union agency decision).

In Argentina, ABS issues were resolved by the national agency for classical biological control, and exports of species of interest to partner organizations resumed. In India, the National Bureau of Plant Genetic Resources and CABI have been collaborating on two plants native to the Himalayas that are invasive in other regions, with net benefits to both of improved ecological research, enhanced engagement for CABI with Indian scientists and especially taxonomists, and ultimately gaining permission to export promising natural enemies to the UK for additional research – which led to the release of the first pathogen for WBC in the UK. Perhaps the most exciting development is in Brazil, the source of so many successful WBC agents yet not so far a recipient or implementer of WBC: a project is coming to fruition that will draw on experience from the outstandingly successful control of an invasive alien rubber-vine species in Australia by an introduced rust pathogen. The plan is to introduce this rust to control a related alien rubber-vine threatening endemic biodiversity in northeast Brazil, including a tree that is sustainably harvested for an economically important wax by the local community – a poster project for the CBD and Nagoya Protocol.

Is this all enough to sustain WBC or is more needed? Moran and Hoffmann conclude by suggesting that although the ISBCW series has been remarkable for its long-running success despite its informal, ad hoc structure and funding, the present threat to the discipline calls for a formal international society to 'wave the flag' and raise the profile of WBC, and under which the ISBCW series could continue to flourish. With regard to non-target effects and precaution, Moran and Hoffman cite a presentation at the 2010 Biological Control for Nature conference that showed that papers reporting non-target effects were cited far more often than papers reporting successful WBC (69 cf. 17 on average). Why is this? And what can be done to change it? The ISBCW series is invaluable for the networking opportunities it provides and its proceedings as a record of what is happening in WBC. But at ISBCW meetings, speakers are preaching to the converted, and it is crucial for the sector to engage exhaustively with other actors and take a place on the world stage as part of global changes: the message that WBC control is the optimum and often only sustainable strategy for invasive alien weeds needs to be heard everywhere.

[1]Moran, V.C. and Hoffmann, J.H. (2015) The fourteen International Symposia on Biological Control of Weeds, 1969–2014: delegates, demographics and inferences from the debate on non-target effects. *Biological Control* 87, 23–31.

The above paper references extensively; limited sources are listed below.

CBD: www.cbd.int/convention/text/

Rio Declaration: www.unep.org/Documents.Multilingual/Default.asp?documentid=78&articleid=1163

Nagoya Protocol: www.cbd.int/abs/text/default.shtml

[2]ISPM No. 3 (1995) *International Standards for Phytosanitary Measures No. 3. Code of conduct for the import and release of exotic biological control agents.* International Plant Protection Convention, FAO, Rome. Revised (2005) as: *International Standards for Phytosanitary Measures 3. Guidelines for the export, shipment, import and release of biological control agents and other beneficial organisms.* www.ippc.int/en/core-activities/standards-setting/ispms/

[3]Wittenberg, R. and Cock, M.J.W. (eds) (2001) *Invasive Alien Species: a Toolkit of Best Prevention and Management Practices.* CABI. www.issg.org/pdf/publications/GISP/Guidelines_Toolkits_BestPractice/Wittenberg&Cock_2001_EN.pdf

[4]IOBC Global Commission on Access and Benefit Sharing: www.iobc-global.org/global_comm_bc_access_benefit_sharing.html

[5]Cock, M.J.W., Biesmeijer, J.C., Cannon, R.J.C., *et al.* (2011) *Climate Change and Invertebrate Genetic Resources for Food and Agriculture: State of Knowledge, Risks and Opportunities.* Commission on Genetic Resources for Food and Agriculture, Background Study Paper No. 54. www.fao.org/docrep/meeting/022/mb390e.pdf

[6]Van Driesche, R.G., Carruthers, R.I., Center, T., *et al.* (2010) Classical biological control for the protection of natural ecosystems. *Biological Control* 54 (suppl. 1), S2–S33.

[7]Sheppard, A.W., Hill, R., DeClerck-Floate, *et al.* (2003) A global review of risk-benefit-cost analysis for the introduction of classical biological control

agents against weeds: a crisis in the making? *Biocontrol News and Information* 24, 91N–108N.

Bringing Together Safer Molecules and Biocontrol Technologies

The very first attempt by the Society for Biocontrol Advancement (SBA) to bring together researchers, practitioners and purveyors of biocontrol and/or safer chemical pesticides turned out to be a resounding success.

On 23 February 2015, a one-day 'National Meeting on New/Safer Molecules and Biocontrol Technologies for Integrated Pest Management in Crops' was jointly organized by SBA and the Indian Council of Agricultural Research's National Bureau of Agricultural Insect Resources (ICAR–NBAIR) in Bengaluru, India. The platform presentations took place in two technical sessions. The first session on new and safer molecules in IPM had key presentations by representatives from DuPont and Bayer CropScience. Papers in the second session on biocontrol technologies for IPM included mass production technologies and safe use of bioagents in conjunction with chemical pesticides so as to create a robust IPM programme. The poster session attracted more than 30 presenters. The wrap-up and way forward session was chaired by Dr Abraham Verghese (President, SBA) and moderated by Dr P. Sreerama Kumar (incoming Vice-President, SBA). Dr Verghese lauded the interest shown by industry and academia in trying to blend chemical insecticides and bioagents in plant protection. The efforts of this attempt would be fruitful if the concept of IPM turns into 'green' IPM. He said that all the barriers between chemicals and biocontrol agents need to be liquidated to achieve this. He suggested integrating *Trichogramma* with safer molecules and gradually phasing out chemicals like carbosulfan. Dr Verghese lamented the lengthy time required for commencing a biocontrol programme because of various hurdles. For example, the average time required for importation of a bioagent could be up to six months, and the usual time required to register a biopesticide is almost two years. He suggested that drastic changes are a must in both policy and regulations governing biocontrol programmes to safeguard the interests of farmers. Scientists should be involved in framing policies on such issues. He noted that ICAR–NBAIR has been in touch with the National Biodiversity Authority to address the policy issues regarding exchange of insect specimens or parts thereof for identification and description of new species. Another issue that needs attention is the strict adherence to the International Organization for Biological Control (IOBC) standards with regard to chemicals and their safety to natural enemies. SBA's General Body Meeting followed the national meeting during which the new Executive Council took charge from the outgoing board.

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Potential Biological Control for Invasive Threat to Galapagos Endemic Birds

A study of birds' nests in western Ecuador[1] uncovered the presence of a muscid bird parasite, *Philornis downsi*, that is invasive in the Galapagos Islands but otherwise known only from Argentina, Brazil and Trinidad and Tobago. The recovery of a *Brachymeria* sp. parasitoid from *P. downsi* during these surveys raises the possibility of a new biological control opportunity.

Larval *P. downsi* feed in nestlings' nares (nostrils) and by rasping skin and feeding on body fluids. The fly infests 17 bird species on Galapagos, including seven Darwin's finches and four other endemic species. Nestling mortality is high, leading to concerns about population declines and potential species extinctions. Percentage parasitism of nests by *P. downsi* in the Galapagos Islands exceeds 90% compared with 12–14% found in western Ecuador. Nest parasitism levels in Ecuador are also lower than recorded for *Philornis* species elsewhere in South America. It is not yet clear whether *Brachymeria* sp. plays a role in suppressing *P. downsi* in western Ecuador but 9–19% parasitoid emergence was recorded from the fly over the two-year study.

[1]Bulgarella, M., Quiroga, M.A., Brito Vera, G.A., *et al.* (2015) *Philornis downsi* (Diptera: Muscidae), an avian nest parasite invasive to the Galápagos Islands, in mainland Ecuador. *Annals of the Entomological Society of America* 108, 242–250.

Bemisia Parasitoid Checklist

An updated list to the world fauna of parasitoid Hymenoptera reared from members in the *Bemisia tabaci* species complex is provided in an open-access paper in *Florida Entomologist*.[1] In total, 112 parasitoid species in five families and seven genera are tabulated along with global distributions and pertinent references to aid accurate identification. Published host–genera associations are reviewed, with some 'dubious' ones noted.

[1]Lahey, Z. and Stansly, P. (2015) An updated list of parasitoid Hymenoptera reared from the *Bemisia tabaci* species complex (Hemiptera: Aleyrodidae). *Florida Entomologist* 98, 456–463.