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General News

Biological Control Protects the Okavango Delta from Salvinia

A paper in *The Open Plant Science Journal* reviews aquatic weeds in Botswana and describes how control of salvinia (*Salvinia molesta*) by the weevil *Cyrtobagous salviniae* is protecting the Okavango Delta, a UNESCO World Heritage Site.[1,2] Key to this success has been the effective legislation for these invasive weeds in Botswana and the Department of Water Affairs (DWA) of Botswana, which seems to respond very quickly to any form of weed infestation.

The paper covers three invasive aquatic plants: salvinia, water lettuce (*Pistia stratiotes*) and water hyacinth (*Eichhornia crassipes*). It reviews species biology, spread, distribution and negative impacts of the weeds, and describes control efforts since the species were first recorded in Botswana, all in the context of regional and global research and control efforts. Important features of the initiatives against the invasive plants are government legislation and community-based initiatives to prevent the importation and spread of aquatic weeds in Botswana, together with collaboration regionally and with CSIRO in Australia. The 215 references include 'grey' literature, and the paper includes published and previously unpublished data. Undertaking the review for Botswana involved collating and analysing information dispersed among many sources in the past five decades.

Salvinia was first recorded in the Namibia–Botswana border area in the Chobe River in 1948. It dispersed along the Kwando-Linyanti-Chobe river system (which feeds into the Zambezi River) and by the end of 1972 it had infested the entire river system. Salvinia reached the Okavango Delta in July 1986. As it spread during the following years, dense mats were recorded along fringing vegetation of rivers, and substantial to complete weed cover of pools, lagoons and lakes. The infestations impeded community activities such as boat transport and fishing, reduced tourism and threatened clean water supplies. Initially, the weed was managed by mechanical or manual removal, physical barriers such as booms, and habitat alteration whereby areas were temporarily drained. Use of herbicides (paraquat, glyphosate) was costly, had unacceptable non-target effects, and was halted in the northern wetlands in 1977.

First attempts at biological control of salvinia were on the recommendation of the Commonwealth Institute of Biological Control in Trinidad (CIBC – now part of CABI). The grasshopper *Paulinia acuminata* and the weevil *Cyrtobagous singularis* were supplied by CIBC, and some 3370 grasshoppers and 1550 weevils were released between 1971 and 1975. The grasshoppers did not thrive, probably because of cold nights and bird predation. The weevil was difficult to monitor because of its small size and cryptic behaviour. The moth *Samea multiplicalis* was released in 1972 but had no discernible impact. Breakthrough came after success with a related weevil, *Cyrtobagous salviniae*, was reported from Australia and was aided by regional activities in southern Africa. Efforts were coordinated through a special working group set up in 1984 by the Southern African Commission for Conservation and Utilization of Soil (a body representing Botswana, Namibia and South Africa), which was merged in 1986 with the Water Sector under the Southern African Development Community. The biological control work also received technical support from CSIRO with visits by Dr Wendy Forno. In Botswana, she undertook seven visits to assist with salvinia biological control between February 1986 and July 1999.

The salvinia weevil *C. salviniae* was imported from CSIRO by the DWA of Namibia in 1982 for mass-rearing and release. By March 2005, staff had released more than 10,000 weevils, and *C. salviniae* had dispersed along the Kwando-Linyanti-Chobe river system. Post-release evaluations found that the weevil did not establish in all areas, as indicated by recurrent occurrence of large salvinia infestations.

Within one week of salvinia being discovered in the Okavango Delta in July 1986, the DWA of Botswana had collected *C. salviniae* from the Kwando River system and introduced it to the infested part of the Delta. Although the salvinia biological control programme had an observable impact, the results were not scientifically assessed until 1998. At that time, systematic monitoring sites in the Kwando-Linyanti-Chobe river system and Okavango Delta were demarcated for the first time. It was demonstrated that *C. salviniae* could effect control of salvinia in Botswana in a timeframe of less than a year for still and slowly moving water bodies and 2–3 years for rapidly flowing rivers. In 1999–2000, *C. salviniae* was redistributed by extracting weevils from highly populated infestations and releasing them into areas where they were scarce, aided by mass-rearing of the weevils in breeding pools. This represented one of the largest releases ever made in the country. By 2003 dense infestations of the weed had been reduced in many of the wetland areas. Currently salvinia is under biological control in six major rivers, nine minor rivers, 23 lagoons/lakes, and 34 wetland pools and ponds in the northern wetlands of Botswana. New, rapidly growing infestations have been observed in some waterbodies since 2010 as a consequence of higher inflows into the Delta than for 30 years bringing new salvinia material with them. But weevils also arriving with the weed brought it under control within 11 months without need for new releases or artificial redistribution. Monitoring for emerging infestations remains important, however, because the salvinia threat is ever-present. Factors such as community fishing, navigation, wild animals (hippopotamus and elephant) in the spread of salvinia are a great challenge in the wetlands.

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In comparison to salvinia, water lettuce and water hyacinth are currently of lesser concern in Botswana's wetlands. Biological control is part of the management strategy for water lettuce, and it is being considered for water hyacinth.

Water lettuce was first recorded in Botswana and Namibia (in the Kwando and Chobe rivers) in 1986. The weevil *Neohydronomus affinis* was imported from CSIRO in 1987 by Botswana, and its release has apparently kept water lettuce in check ever since on the river system, although no post-release evaluation has been reported. Elsewhere in Botswana infestations were sporadic but sometimes high, depending on rainfall. The weed is managed mostly by manual removal before it sets seed, and by regulating water flow where necessary; for example, temporary draining of infested canals or lakes allows it to be locally eradicated.

Water hyacinth has been reported in Botswana only from the Limpopo river system on the border with South Africa. Arriving via the Crocodile River in South Africa, it was first recorded in the Limpopo in May 2010. By 2014 it had spread along its entire length. Workshops were held with scientists from South Africa in 2010 and 2013, which called for a joint management plan. A helicopter survey in 2012 showed the extent of the problem, and an extensive land-based survey was carried out in Botswana in 2013. Some physical removal of the weed was carried out in some areas. Filters were trialled with limited success as they became quickly clogged. Then a flash flood in 2014 swept the water hyacinth plants downriver, so for the time being the threat has receded. But the Limpopo basin remains vulnerable to this species.

Botswana's wetlands are part of a network across southern Africa that plays a critical role in the ecological and livelihood security of the region. Biological control is a cornerstone of the Government of Botswana's policy of monitoring and rapid response to counter the threat to its wetlands from invasive alien species. The designation of the Okavango Swamp as a UNESCO World Heritage Site adds another dimension. World Heritage Sites are "considered to be of outstanding value to humanity" … "for whose protection it is the duty of the international community as a whole to cooperate" in the face of diverse threats. Botswana's efforts to protect the Okavango Swamp from invasive alien weeds illustrate how national, regional and international cooperation in biological control can help preserve World Heritage Sites in line with the World Heritage Convention.

[1] Kurugundla, C.N., Mathangwane, B., Sakuringwa, S. and Katorah, G. (2016) Alien invasive aquatic plant species in Botswana: historical perspective and management. *The Open Plant Science Journal* 9, 1–40.

[2] whc.unesco.org/en/conventiontext/

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Biological Control for the Protection of a Recently Proposed World Heritage Site in South Africa

Biological control plays an important role in protecting South Africa's natural heritage from the damage inflicted by invasive alien plants. One of the best examples of this is the control of the invasive cactus, *Opuntia stricta*, in the Kruger National Park using the cochineal biocontrol agent *Dactylopius opuntiae*. This programme has resulted in the permanent control of *O. stricta* and the protection of indigenous biodiversity in this very important and internationally renowned protected area. A more recent release of a biocontrol agent against another invasive cactus will hopefully also result in the protection of both our cultural and natural heritage at the Sibudu Cave, a site that has been proposed as a new UNESCO World Heritage Site.

The Sibudu Cave is regarded as a site of "outstanding universal value" by archaeologists owing to the immense contribution that the site has already made to our understanding of early human history. There is evidence of human settlement at the site from as long ago as 80,000 years and it is rich in artefacts from the Middle Stone Age, an important period for studies of the cultural evolution of modern humans at around the time that our species first left Africa. Sibudu has yielded the oldest ever arrowheads and the oldest ever bone needles, as well as the oldest beds, which were made from sedges and a plant with insect repellent properties.

An application for the site to be recognized as a UNESCO World Heritage Site was submitted in 2015; this proposal included plans to open a visitors' centre, to employ heritage guides to educate visitors, and to protect the land in the immediate area of the site from development with a 40-ha core zone and a 200-ha buffer zone. The site of the archaeological dig is in a shallow cave in a cliff near the Tongati River in KwaZulu-Natal. The forest vegetation along the river is heavily invaded by a number of invasive alien species but the worst of them is the primitive creeping cactus, *Pereskia aculeata*. This species grows in a dense monoculture under the forest canopy, covers large areas of the cliffs and grows within metres of the archaeological dig site itself.

Pereskia aculeata was first recorded in South Africa in 1858 when it was grown as a specimen in a botanical garden in Cape Town. It was only in the 1970s that it was first recorded as a problematic plant and a threat to indigenous biodiversity. It is now considered one of the worst weeds in South Africa and is abundant in the warmer subtropical parts of the country. It dominates the understorey of forests and covers the canopies of large forest trees which often collapse under the weight of the weed, resulting in a light gap dominated by *P. aculeata*. The creeping habit of the plant, and its ability to regenerate from any small fragment of stem, make it a difficult target for physical or chemical control. Biological control is therefore considered the only possible option for sustainable control.

South African entomologists started looking for natural enemies of *P. aculeata* in the native distribution of South America during the 1980s. During these early surveys, *P. aculeata* was not the main target species and collection of potential agents was done opportunistically. The early surveys were, however, successful in sourcing the first biocontrol agent for *P. aculeata*: the flea-beetle, *Phenrica guerini* (Chrysomelidae). This beetle feeds externally on the leaves of *Pereskia aculeata* as a larva and an adult. It was first released in 1991 and, although establishment success rates have been relatively low, it is damaging at a minimum of five sites in the country where it reduces the number of leaves of *P. aculeata* by over 150 leaves per metre squared. Despite the success of *Phenrica guerini* at a few sites in South Africa it was clear that more agents were required to reduce the negative impacts of *Pereskia aculeata* to acceptable levels.

In 2012, a survey for new agents was conducted, resulting in the importation of the pereskia stem-wilter, *Catorhintha schaffneri* (Coreidae). Host-specificity testing studies indicated that the species was monophagous, feeding only on *P. aculeata*, and that the agent was safe for release in South Africa. Permission for release was granted in 2014 and the first release was made in October 2014. *Catorhintha schaffneri* feeds on the shoot tips of *P. aculeata* and causes the shoots to split and rot. It is now the second summer season after it was first released and the initial levels of damage that have been recorded are very promising. Biological control is a long-term solution, and not a quick fix, so it will take many years before we know exactly how effective *C. schaffneri* is, but at one site where the agent was released, 95% of the shoot tips of *P. aculeata* were damaged and a 10% reduction in cover of *P. aculeata* was recorded during a single summer.

The pereskia stem-wilter was released at Sibudu in April this year. It was released within a few metres of the main dig, an area where physical and chemical control may cause damage to ancient artefacts. Hopefully the agent will thrive at Sibudu and protect the natural and cultural heritage at this recently proposed UNESCO World Heritage Site.

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India's National Bureau of Agricultural Insect Resources Bags Two National Awards

Bengaluru-based National Bureau of Agricultural Insect Resources (NBAIR) has been awarded the prestigious Sardar Patel Outstanding ICAR Institution Award (Small Institutes) for 2015 having been adjudged the best from among 34 institutes spread across India. It is pertinent to note here that NBAIR, in its earlier version as the Project Directorate of Biological Control, had won the same award in 1998. This Bureau, the youngest of the six bureaus under the Indian Council of Agricultural Research (ICAR), is undertaking the onerous task of documenting *in toto* the entire agricultural insect and related arthropod diversity of the country, including the associated organisms such as pathogens and other microbes. More importantly, research and development of biological control has been its mainstay. It caters to the needs of students, researchers, biocontrol entrepreneurs and the farming community of the country.

The accomplishments of the Bureau, operating out of the erstwhile Commonwealth Institute of Biological Control (Indian Station) at Hebbal, are many. Over a 100 new species of insects, many of them natural enemies of pests of agricultural and horticultural crops, have been discovered by its scientists. Web-based guides with high-resolution photographs to aid all those engaged in the identification of insects of agricultural importance have been developed and hosted on the NBAIR website (www.nbair.res.in). With the generation of DNA barcodes for well over 700 insects, the Bureau leads the country in this much-needed activity. As a national repository for agricultural insects, it houses over 100 live insect cultures (of a few pests and a number of parasitoids and predators) to support entomological research and to enable the management of insect pests of crops through biological means. It is the sole institution in the country to combine an array of entomological capabilities from the identification of pests to the development and formulation of strategies for the management of crop pests utilizing non-pesticide methods. The research excellence on the entomological front, and the service it renders to the farming community by providing bioagents for sustainable pest management, has paved way for its selection as the outstanding institution by ICAR.

Another feather in its cap is the Panjabrao Deshmukh Outstanding Woman Agricultural Scientist Award for 2015 going to Dr Chandish R. Ballal, who took charge as Director of NBAIR on 18 July 2016. Dr Ballal's research has focused on standardizing effective production technologies for host insects and for some of the most promising parasitoids and predators. She has formulated economically viable, simple and efficient mass-production protocols for a number of insects of agricultural importance. Her laboratory is the only source in the country for prompt and regular supply of authentic cultures of a wide range of natural enemies and other insects which form the cornerstone for research by students and biocontrol scientists. It also backs up the constant needs of commercial insectaries. With the year-round maintenance of 117 different insect cultures she controls one of the largest live insect repositories in the world. She has identified native bioagents for the management of important crop pests and formulated their modes of production and utilization. The mass-production protocols developed by her for several host insects, ichneumonids, anthocorids and predatory mites need special mention as they are first of their kind in the country. By interacting with farmers and conducting demonstration trials in farmers' fields she has substantially contributed to building confidence in farmers on the efficacy of this non-chemical mode of pest management. Through her publications, training programmes, farmer interactions and supply of quality natural enemies, she has made sustained efforts to popularize biological control as an essential component of integrated pest management in the country.

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Les Ehler, 1946–2016

Lester Ervin 'Les' Ehler died on 2 September 2016 at the age of 70. A noted entomologist, biological control specialist, and teacher, he was Emeritus Professor of Entomology at the University of California (UC) Davis. Entomologist Michael Parrella, his contemporary and later Associate Dean of Agricultural Sciences in the College of Agricultural and Environmental Sciences, describes him as "the heart and soul of biological control at UC Davis." Admiration and affection for him from colleagues and collaborators is reflected in an appreciation posted by the Department of Entomology and Nematology (which this article draws on):
Web: http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=22031

Les was born on 6 January 1946 in Lubbock County, Texas. He grew up on the family farm and developed a life-long interest in insects from an early age. After gaining a Bachelor's degree in entomology from Texas Tech University in 1968, he acquired training and experience in classical biological control during his PhD studies at UC Berkeley. He joined the Department of Entomology at UC Davis in 1973 as its first biological control specialist, and promoted it as an important strategy for integrated pest management. In the 1980s, he led a team that documented the impact of malathion-bait sprays for Mediterranean fruit fly on pollinators and natural enemies of pests, showing how this could lead to pest outbreaks of a native insect. In 1985 he became Professor of Entomology and entomologist in the UC Davis Experiment Station, from which he retired in January 2008.

He was a national leader in biological control and chaired the Entomological Society of America's Biological Control Section. He was active internationally, serving as President of the International Organization for Biological Control (IOBC) for a four-year term from 2000. His lasting contribution to biological control, stemming at least in part from his flair for field work and affinity with farmers, is to have championed greater implementation of biological control based on good science. He brought the all-important issue of barriers to application to a subject at the time rather focused in academia on theoretical ideas rather than uptake. This is encapsulated by the 1990 volume, *Critical Issues in Biological Control*, which he co-edited as an output of the XVIII International Congress of Entomology (Vancouver, 1988). It placed emphasis on scientific issues that needed to be addressed to advance practical biological control. An advocate for engaging with new ideas, he was lead-editor of the 2004 title *Genetics, Evolution and Biological Control*. This volume, based on keynote addresses at the Third IOBC International Symposium in 2002, highlighted potential applications to practical biological control of what was then the newly emerging discipline of genomics. He was a champion of conservation biological control. In his opening chapter to the 1998 book *Conservation Biological Control* (ed. Pedro Barbosa) he again highlighted the need for management techniques developed in academic studies to be transferred to production agriculture.

During his time at UC Davis he led many initiatives whose success owed much to his combination of sound ecological research skills and entomological knowledge, alongside determination to apply these to improve practical biological control – as his work with obscure scale on oaks illustrates. From the 1960s, native and exotic oak (*Quercus*) species in Sacramento's Capitol Park in northern California became infested with obscure scale (*Melanaspis obscura*). Previous Californian infestations had been eradicated by pesticides but this failed in Sacramento. He began a biocontrol project in 1983, developing an optimum introduction strategy by analysing the parasite guild on the scale in Texas, part of its native range. This led to the selection of *Encarsia aurantii* as the agent with best attributes for California. It was first released in 1987 and by 2002 it had achieved complete control.

Larry Godfrey, extension entomologist in the Department of Entomology and Nematology, describes how Les made major contributions to understanding of stink bug ecology and their biological control, and this underpinned development of a management system for organic tomato farmers in California. He showed how natural enemies contribute to population suppression, but that habitat management was key. Stink bugs invade tomato crops during their second generation in June. Working with farmers, he developed a system to reduce this colonizing population by managing first the damp leaf litter that provides overwintering sites, and then the first-generation host plants (notably mustard/wild radish weeds). By planting them as a trap crop that is destroyed before the first generation of stink bugs mature, organic farmer Robert Ramming said stink bug infestations can be reduced by 90%.

According to Harry Kaya, Emeritus Professor in the same Department, Les continued to work with the farmers in retirement. Harry also describes how he bought a boat and took up fishing. Applying his customary planning and diligence and learning from experts, he went from novice to expert and enjoyed taking Harry and many others fishing on California's rivers and lakes.

Les Ehler will be remembered by the biological control community as man who carried on the tradition of the pioneers who developed biological control as a practical subject, and for bringing renewed focus to its practical application. Larry Godfrey and Jay Rosenheim are organizing a symposium for Les at the Pacific Branch Entomological Society in Portland, Oregon in April next year.

New Zealand Scores More World Firsts

Two more exotic species are set to discover that New Zealand is not sufficiently distant to escape the natural enemies in their areas of origin in the Northern Hemisphere. In May this year, the Environmental Protection Authority approved two biocontrol agents for *Hypericum androsaemum* (tutsan) and one for *Equisetum arvense* (field horsetail).

Tutsan

Tutsan, an evergreen shrub native to Europe and western Asia, is a very visible semi-evergreen weed in high-rainfall areas of central North Island. The bushy shrubs are covered in bright yellow flowers in summer. These are succeeded by black berries, which are dispersed by birds and probably possums. Since it was first recognized as a 'weed of significance' in 1955, tutsan has invaded both agricultural and conservation land. It is a particular problem in pasture because it is unpalatable to livestock and forms large, dense stands. Tutsan has also naturalized in Australia, Chile and possibly the USA, but Landcare Research, on behalf of the Tutsan Action Group (a farmer-led group supported by Horizons Regional Council), is conducting the first biological control project to release agents against it.

Tutsan is also found in New Zealand's South Island, where it is not considered a problem. The difference may be attributed to different origins of the two populations, and also a 'hitch-hiker' natural enemy. Genetic analysis indicated that tutsan in North Island and South Island are largely different genotypes, suggesting separate introductions. North Island populations largely resemble a genotype restricted to western/northern parts of the British Isles, while those in South Island match a genotype more widely distributed in western Europe (across the British Isles, France and Spain). In addition, during surveys for natural enemies in New Zealand, a rust pathogen, *Melampsora hypericorum*, was recovered from tutsan in both North Island and South Island: one genotype was identified in North Island and a different one in South Island. The rust may be keeping tutsan in check in one population but not the other. This is supported by findings of both surveys in Europe and laboratory tests of European and New Zealand material by CABI. The plant genotype found in South Island is the more susceptible to *M. hypericorum*. In Europe, the tutsan genotype found in South Island suffers the heaviest rust infections, while infection of the genotype found in North Island is very variable and most likely resistant.

New Zealand is sometimes in the enviable position of having no native species of a potential weed biological control target, and this has allowed host-specificity testing to be successfully completed while it stalls in other countries. But there are 19 *Hypericum* species in New Zealand; one of them is another invasive weed (*H. perforatum* or St John's wort) but four are native species, including one (*H. minutiflorum*) that is critically endangered.

In 2012–2013, Landcare Research engaged CABI to undertake surveys of tutsan in three biogeographical regions in the same climate categories as invaded regions of New Zealand: the British Isles and northern France, southwestern France and northern Spain, and the Caucasus region of Georgia. Despite the likely origins of tutsan in New Zealand, the two most promising natural enemies were collected in Georgia: a biotype of the tortricid moth *Lathronympha strigana* (the species is widespread on *Hypericum* spp. throughout Europe but this was suspected to be specialized on tutsan) and the chrysomelid beetle *Chrysolina abchasica* (known only from the Caucasus region). These were shipped to New Zealand in 2014, where both proved to be highly damaging to tutsan in containment testing: the moth attacks the stems, shoot tips and seed pods, while the beetle attacks the foliage.

The moth passed host-specificity testing with flying colours: female moths laid eggs only on *Hypericum* plants, with a preference for tutsan, and the emerging larvae survived only on tutsan and St John's wort. This indicated there was no significant risk of non-target attack on other *Hypericum*, including the native species.

The leaf beetle results were less clear-cut: in no-choice tests in the laboratory, two native *Hypericum* species (*H. pusillum* and *H. rubicundulum*) proved to be fundamental hosts, i.e. they supported complete development from egg to adult, although most of the emerging adults died soon after emergence. Was this a laboratory 'false positive' or would the leaf beetle be a threat to native *Hypericum* spp. in the field? To assess this, the Landcare Research scientists drew on research in the government-funded 'Beating Weeds' programme, which showed that the relative performance of agents in laboratory trials on a test plant versus the target weed is a good predictor of whether a fundamental host will actually be attacked in the field. They also compared it with *Chrysolina* species released more than 50 years ago against St John's wort. They concluded that *C. abchasica* was less of a risk than the St John's wort biocontrol agents. During laboratory testing St John's wort beetles attacked all *Hypericum* species presented to them including native species, and completed development on two native species. Yet in the decades since they were released they have not inflicted significant damage on native *Hypericum* species.

If all goes well, first releases for both agents are planned for this coming New Zealand summer. Rearing difficulties are making it challenging to produce large numbers of adults for field release.

Field Horsetail

Field horsetail has a wider distribution than tutsan, extending across temperate and arctic regions of the Northern Hemisphere, and the recently approved biocontrol agent, the weevil *Grypus equiseti*, is also native across these regions. Landcare Research scientists led this project, another world first, on behalf of another farmer-led group, the Rangitikei Horsetail Group.

Field horsetail is an ancient species related to ferns: fossil specimens date back some three million years to the Carboniferous period. It also has medicinal uses in Europe dating back 2000 years, and research indicates it produces compounds with anti-microbial properties – but in large doses it can be toxic to horses, especially, although the high silica content of stems means the plant is generally avoided by grazing animals. While it can sometimes become a crop weed in the temperate Northern Hemisphere, it has become a significant invasive problem in some countries of the Southern Hemisphere. It spreads by spores, but also develops extensive underground rhizomes that are not amenable to herbicide control. It was first recorded in New Zealand in 1922. It forms dense stands in damp habitats and in riparian areas, and is starting to show signs of rapid spread.

Unlike tutsan, this *is* a target species with no relatives – native or otherwise – in New Zealand, and has numerous natural enemies in the native range. So hopes were high that host-specificity testing would not be onerous or expensive, and would be successful. Surveys for potentially suitable agents were conducted in 2013–2014 by CABI staff at numerous field horsetail sites in southern England, which has a reasonably good climate match to large areas invaded by field horsetail in New Zealand.

Among natural enemies that elicited interest were a flea beetle (*Hippuriphila modeeri*), a weevil (*Grypus equiseti*) and sawflies (*Dolerus germanicus* and *D. eversmanni*). Shipments of these species were made to Landcare Research containment facility where host-range tests were conducted in 2013–2015. The weevil was prioritized as, in this most promising species, both larvae and adults feed on the target plant. Testing showed that *G. equiseti* was specific to field horsetail, and the larvae in particular were very damaging: they mine in the stems and down into the rhizome, and reduce the plant's ability to produce new shoots, which should reduce its invasiveness. This species had been found at only one site surveyed by CABI. Initially shipments provided material for host testing, while further collections and shipment in subsequent years have allowed Landcare Research to mass-rear weevils for release. There is hope that *G. equiseti* may be that rare find among biocontrol agents: a silver bullet. First releases are expected in late 2016.

Both the field horsetail and tutsan projects are funded by the Ministry for Primary Industries' Sustainable Farming Fund, with co-funding provided by a range of other organizations, including the National Biocontrol Collective.

Main source: Hayes, L. (2016) Three new agents approved for two weeds. *Weed Biocontrol: What's New?* 77, 6. Landcare Research New Zealand Ltd 2016.

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Weed Biological Control in the Pacific

Biological control of invasive weeds in the Pacific began over a century ago, in 1911, with the introduction of an agent against *Lantana camara* in Fiji and New Caledonia. Two open-access publications in *NeoBiota* review weed biological control initiatives in Pacific island countries and territories (PICTs)[1] and specifically in Vanuatu[2]. The authors highlight difficulties faced by the small and geographically dispersed PICTs in implementing classical biological control, but how they can share experiences with each other and benefit from research and programmes in countries further afield to tackle common invasive weed problems.

Day and Winston[1] review the current status and potential for further weed biological control in the 22 PICTs. They used the 'World Catalogue'[3], and more recent publications and personal communications to compile a dataset on biological control initiatives in each PICT. They used numerous (including unpublished) resources to collate information on invasive weed distribution in each PICT, and compared the identified weeds with weed targets in biocontrol initiatives worldwide (past, current and potential). They then identified what biocontrol agent(s) could be considered for introduction in a PICT where a target weed occurs but no biological control has been undertaken.

At least one biocontrol agent species has been intentionally introduced in 17 of the 22 PICTs, with Fiji and Papua New Guinea the most active (introducing 11 and 12 agents, respectively). Since the 1950s there has been a fairly steady rate of introductions. In all, 62 biocontrol agents have been introduced against 21 target weeds (including two *Sida* species as a single target). Of these 32 agents established from deliberate introductions against 17 weed species; two agents did not initially establish, but later spread into the region, while two agents were inadvertent introductions. The paper tabulates each biocontrol agent, its target weed(s) and PICTs where it has been introduced, together with an assessment of establishment and impact for each PICT, and flagging other PICTs where the weed is present and the agent is considered suitable to consider for introduction.

Six invasive weeds (seven if the *Sida* spp. are counted individually) are considered to be under complete control overall. The most commonly controlled target is *Mimosa diplotricha*, which is widespread in PICTs and complete control has been reported in 13 countries. Complete control of *Sida* spp., *Salvinia molesta, Tribulus cistoides* and two *Opuntia* targets is also recorded. Control of a further six weeds is classified as partial to complete, impacts on two others have been variable, and are absent or unknown for three more. For four of the targets, biocontrol agent introductions are recent and establishment and impact are still being assessed.

The study identified a number of biocontrol agents with high impacts that have not been released in all PICTs reporting the relevant weed problem. For example, the leaf beetle *Calligrapha pantherina* has controlled two *Sida* species in Fiji, Papua New Guinea and Vanuatu, but could potentially be introduced against *Sida* spp. in up to 18 other PICTs. In some cases, a biocontrol agent introduced against a weed in one PICT could be effective against a related target species in another PICT. For example, the cactus moth *Cactoblastis cactorum* has controlled *Opuntia stricta* in New Caledonia, but also attacks *O. monacantha*, which is recorded as invasive in 13 other PICTs. In theory – and generally in practice – re-distributing biocontrol agents between PICTs will reduce cost and time implications for a biocontrol project partly because host-range testing for one PICT will cover many non-target species common to the region. Choice of agent may also be easier: where agents have been long-established in at least one PICT, the most effective agents for the region may be clear and any unanticipated non-target effects already identified. There are two caveats. First, each PICT should survey to check that the proposed biocontrol agent is not already in the country through inadvertent introduction or natural spread. Second, each PICT would need to consider whether additional (native/endemic, crop, culturally significant) species need testing. Such additional testing could, though, be expedited if rearing and testing methods for the biocontrol agent suitable for the region have already been developed.

A lengthier and therefore more expensive option is to consider biocontrol agents that have been used successfully outside the Pacific region. This could be appropriate for target weeds of high density and impact – for example, giant cane (*Arundo donax*), which is present in 12 PICTs. Introducing additional agents from other regions could also be considered where biological control has been implemented in the Pacific but is not adequate – for example for *Lantana camara*. In this approach, though, host-specificity testing for plants of importance in the Pacific and suitability studies such as climate-matching will be critical.

The goal of this study was to provide an information resource for PICTs, so that biological control can be used in the Pacific region to reduce the impact of invasive weeds, to the benefit of food security. For over half the weed species so far targeted, biocontrol agents are having a medium to high impact, illustrating the efficacy of the approach.

Vanuatu

Vanuatu provides a case study of how a PICT has used biological control for invasive weeds[2]. The first biocontrol agent was introduced to Vanuatu in 1935 against *Lantana camara*. In total, nine agents have been introduced against eight target weeds – one has only recently been introduced, and of the other eight only one failed to establish. Six further agents arrived accidentally in Vanuatu (four on *L. camara*).

Sida spp. biological control is the outstanding success story, and an example of intra-Pacific technology transfer: *Calligrapha pantherina* was introduced in 2005 from Fiji (to where it was introduced from Australia in 1989). Complete control of *S. acuta* has been recorded where the biocontrol agent is present. It is less effective against *S. rhombifolia*, but this species is less invasive in Vanuatu, and it is anticipated that the biocontrol agent will be able to maintain it at low density. The agent was originally released at 45 sites on 14 islands; surveys eight years post-release found it had spread to 30 islands including all the major islands, though it was not possible to survey small, remote islands. Farmers reporting the need to control *Sida* spp. fell from 96% pre-release to 14%, and 78% of farmers said that production had increased by more than 50%.

Several of the introduced biocontrol agents are helping to control some other important invasive weeds in Vanuatu, and recently introduced agents are likely to enhance this, to the benefit of farmers. An interesting exception is *Mimosa diplotricha*, which is still not under control although the psyllid *Heteropsylla spinulosa*, which has been successful elsewhere across the Pacific, was released in 1994. Surveys in 2012–2015 did not recover it (though psyllid-like damage was recorded) and the plant is still a serious invader in the country.

The paper identifies a number of additional biocontrol agents that could be introduced from other PICTs, including additional agents for *L. camara*, and agents for two emerging weed targets in Vanuatu: cat's claw creeper, *Dolinchandra unguis-cati*, and African tulip tree, *Spathodea campanulata*.

All nine deliberately introduced biocontrol agents in Vanuatu had previously been released in other countries. Besides the benefits of this approach described above, it overcomes infrastructure obstacles: some PICTs may not have the necessary facilities or technical expertise to undertake testing. Introducing a tried-and-tested biocontrol agent gives an opportunity for national staff to gain relevant expertise. There are also downsides, partly because many biological control projects in the Pacific are donor-funded and tend to be selected on the basis of likely success. This may mean a weed of high importance to a specific PICT is not selected either because it is seen as a difficult target or because it is not a serious weed in other PICTs. The limited timeframe of projects also means that releases may be done on a limited number of islands, and post-release monitoring may not be funded. Nevertheless, the paper concludes that biological control projects to date have given Vanuatu a firm foundation on which to build: the next challenge is to secure funds for weeds that have not been targets of biological control anywhere in the world.

[1] Day, M.D. and Winston, R.L. (2016) Biological control of weeds in the 22 Pacific island countries and territories: current status and future prospects. *NeoBiota* 30, 167–192.

[2] Day, M.D. and Bule, S. (2016) The status of weed biological control in Vanuatu. *NeoBiota* 30, 151–166.

Both papers were presented at the 13th International EMAPi conference in Waikoloa, Hawaii.

[3]Winston, R.L., Schwarzländer, M., Hinz, H.L., Day, M.D., Cock, M.J.W. and Julien, M.H. (2014) *Biological Control of Weeds: A World Catalogue of Agents and Their Target Weeds*. USDA Forest Service, Forest Health Technology Enterprise Team, Morgantown, West Virginia, USA.

Conference Report

ICE in Florida

Entomology without Borders, the XXV International Congress of Entomology (ICE) was held on 25–30 September 2016 at Orlando in Florida, USA. This gathering of worldwide entomologists in a city popular for its tourism was an immense event. The Entomological Society of America and Florida Entomological Society held their meetings concurrently with the Congress. Therefore, it is no small wonder that registrants comprised 6682 delegates from 102 countries. With 2857 talks in symposia, 1564 contributed oral papers and 975 posters, it was only possible to hear and see a small portion of all the research and new information presented.

There were 13 symposia relevant to biological control and insect pathology. Their themes included biological control in the 21st century, biological control of brown marmorated stink bug, induced plant defences and biocontrol, parasitoid assemblages, behavioural ecology of entomopathogenic nematodes and ladybird beetles, classical biological control of weeds, *Trichogramma* in augmentative biological control, virus–insect interactions, and biological control of invasive forest insects. Some of the talks were quite disappointing because the content did not live up to the expectation created by their titles. But many presentations gave summaries of new research and results that will fortify the implementation of biological control.

The symposium 'Biocontrol and Induced Plant Defences: a Tale of Tritrophic Levels' had a few topics of notable interest. There was one talk that discussed the potential of genetically modified (GM) cabbage that produces volatile substances that resist attack by diamondback moth yet also attract parasitoids of the pest. This led to a brief discussion on public acceptance of GM crops, particularly in Europe and especially with 'untouchable' staple crops. Another talk provided information on the role of silicon augmentation in crops and the observation that some plants with elevated silicon levels are more attractive to insect predators, possibly through effects on release of host-induced plant volatiles. Finally, one presentation described how studies showed that when caterpillars co-occurred with aphids, there were fewer aphid parasitoids, so that one method to increase parasitization rates of aphids is to properly manage the caterpillar populations.

There were quite a few poster and oral presentations about the use of entomopathogens for control of various arthropod pests; however, you had to search for them in the various programmes and symposia. The presentation themes ranged from laboratory screening trials of native isolates or commercially available entomopathogenic products with other chemical insecticides, to several years of field research for the management of arthropod pests of agriculture, landscape, horticulture or fruiting crops grown in many different parts of the world – from Canada to New Zealand. A highlight was the symposium on the 'Regional Status of Microbial Control Programs' sponsored by the US multistate Working Group on Improving the Microbial Control of Insect Pests, which provided a worldwide perspective on the status and importance of microbial control in arthropod pest management. Presentation titles ranged from 'Integration of microbial biopesticides in greenhouse floriculture: the Canadian experience', to 'Microbial control programmes in eastern Africa', to 'Microbial control: progress from New Zealand'. Other highlights were interesting presentations such as 'Management of ambrosia beetles using entomopathogenic fungi', 'Controlling pests in open field eggplant grown in Florida with predatory mites and *Metarhizium anisopliae*', 'Field testing of a novel system for dissemination of an entomopathogenic fungus, *Isaria fumosorosea*, to control the Asian citrus psyllid, *Diaphorina citri*', 'Development of insect pathogenic fungi *Beauveria bassiana* … as endophytic fungi and effect on plant growth of upland rice' and 'Fungal pathogens for control of cassava pests'. In addition, there were many new or improved entomopathogenic products displayed at various booths in the exhibition hall, such as the novel fungal biopesticide BotaniGard® MAXX produced by BioWorks, which contains pyrethrins plus *Beauveria bassiana*. This product has a unique strategy for controlling insects by using a 'stress and kill' synergistic approach.

At the symposium 'Status and Prospects for Biological Control in the 21st Century', the speakers talked about the challenges for the implementation and research on biological control worldwide. Ensuring the safety of biological control by evaluating benefits and possible risks of the introduction of biocontrol agents is the main priority for current and future biocontrol projects. Environmental problems caused by unsatisfactory practice of biological control in the past have reduced the credibility of people that promote this management method; therefore, a thorough study of the safety of this technique was endorsed to ensure environmental conservation and protection of native and endemic species. Advances in the field of genomics is considered a promising area to increase the success of biological control by adding traits that could help in the adaptation of introduced species into new environments.

On the other hand, speakers pointed out many obstacles that can limit the usage of biological control. Restrictive regulations and slow processes for the importation and release of natural enemies can hinder the implementation of biological control. Poor communication and collaboration among researchers and their fragmented efforts in biological control (e.g. weed, insect and disease biological control as separate disciplines) have also decelerated its growth. Lack of communication with the public and their low participation in research has caused misunderstanding of biological control by farmers, who perceive it as a very complex method difficult to implement. Finally, funding to support biocontrol projects is decreasing. Advances in biological control in the 21st century require a more intensive evaluation of risks and collaborative efforts among the scientist, public and legislature.

Overall, the Congress was informative, well executed and intense. The event and symposia organizers should be applauded for the excellent results from their efforts. Now we look forward to the 2020 International Congress of Entomology in Helsinki, Finland.

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