Editorial

The principal role of this journal is to provide information on scientific research in biological control. Through its News, however, it has focused on some important issues in the periphery of biological control, but of considerable relevance to it. One of these has been biotechnology. Biotechnologies for plant protection, epitomized by *Bt* crops, will particularly influence biological control through their impact on the development of regulatory procedures, their effect on the production and use of biopesticides, and through the way they are incorporated into IPM systems. One current concern is that these technologies will, indeed, not be treated as components of IPM at all, but as hi-tech alternatives to IPM. The risk is that biotechnologies will ultimately fail if insufficient attention is paid to ecological processes such as resistance development, non-target effects and the dynamics of pest complexes as we move from a pesticide-based to a biotechnology-based control system for just one pest species.

Biological control shares with plant resistance (and hence with these biotechnologies) the desirable feature that it can be self-renewing and potentially free to the farmer. In principle, and politics aside, this allows these two key components of IPM to benefit both the wealthy and the poor. It would be a great pity if the new capacity in plant resistance provided by transgenic crops were wasted through a failure to integrate their use with biological control and other components to make locally sustainable IPM systems. In this issue, we announce the creation of a new international working group to examine the integration of biotechnology with biological control in IPM. We hope that biological control practitioners will respond through this and other activities to the challenge to study, understand and share the opportunities and threats which transgenic crops pose to improving sustainable pest management.

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General News

Aliens Make Waves

Biocontrollers may soon be heading for the beach. Invaders from across the sea are giving marine biologists around the world a bad fit of *mal-de-mer* as they see native *fruits-de-mer* put at risk by alien species. The marine environment offers fewer barriers than found on land to the regional spread of invasive organisms. Ocean currents speed dispersal within a region, but help from the planet's most invasive species – *Homo sapiens* – is necessary to transfer species to new regions where they may become noxious pests. There are several important vectors – the aquarium industry, aquaculture, the bait industry, and shipping. In any one week, 10,000 or more species may be transported around the world attached to the hulls or in the sea chests and ballast water of ships. This latter source has been identified as one of the major culprits of alien marine introductions – an average-sized tanker carries an estimated 244 million large planktonic individuals (7000 per cubic metre) during periods of high plankton productivity. Although notable successes have been recorded for biological control in freshwater systems, it has never before been attempted in a marine environment. Armand Kuris from the University of California at Santa Barbara argues that there has been a fatalistic attitude to marine pests: alien species are detected and impact studies made, and it is then tacitly accepted that nothing can be done. But there are signs that the tide is on the turn. From the Pacific Coast of the USA, through the Mediterranean, to Australia, marine biologists are seriously considering the introduction of exotic natural enemies for a range of pests.

Barnacle May Fit the Bill

The European green crab, *Carcinus maenas,* was introduced to the eastern seaboard of the USA some 200 years ago and is frequently held responsible for decimating the soft-shell clam industry in the 1950s in Maine and the Canadian Maritimes. It was first recorded on the West Coast from San Francisco Bay in 1989/90, and since then has moved northwards at an alarming rate of well over 100 miles (160 km) a year, and this, says Kuris, represents the fastest marine expansion of any marine animal, anywhere, ever. It escaped from San Francisco Bay in 1994, reaching Bodega and Tomales bays, about 50 miles (80 km) north of there. Then it exploded into Humboldt Bay in 1995, Cocos Bay in 1996, and Willapa Bay and Grays Harbor in Washington State in 1998. It is considered to be a serious threat to the fisheries and mariculture industry of the Pacific Northwest (with an estimated value of US$45 million/year) and wildlife. Native birds and Dungeness crabs have been singled out as particularly at risk, from predation and/or competition. The Washington Department of Fish and Wildlife has enacted emergency regulations in a probably futile attempt to try and halt its onward spread to Puget Sound.

A native of the Atlantic coasts of Europe and northern Africa, in its home range the green crab is found in protected rocky, sandy and tidal habitats. It feeds voraciously, often on bivalve molluscs and particularly mussels, and has a significant impact on populations of these. Preliminary results suggest that it has a similar and perhaps more substantial impact in its introduced range: dramatic declines in other crab and bivalve species have been measured in California and Tasmania. In the summer of 1996, *Carcinus'* predatory activities led to the loss of almost one-half of the Manila clam stock under culture in benthic mesh bags in one shellfish operation in a central Californian bay. Native shore crab population declines are greater than 90% in some areas.

The crab has many of the classical attributes of a successful invasive species. Kuris identifies its outstanding dispersal and recruitment abilities as key to its success as an invader. It also has high reproductive and growth rates, and wide environmental tolerances. It is omnivorous and opportunistic, capable of learning and improving its prey handling skills. Its body and claws are well armoured, enabling it to crush bivalves unavailable to other crabs, and potentially increase its resistance to predation. In some areas it has relatively novel predatory abilities as it is larger and more agile than native crabs. These attributes make it, according to Kuris, a worst-type case of introduced pest.

A study that compared populations of green crabs from Europe with those from all areas of the world where the green crab has been introduced, found that the introduced populations seemed to be experiencing a release from their natural enemies. Green crabs in introduced populations lacked any parasitism that had direct effects on reproduction, and they reached larger sizes and lost fewer limbs than their European counterparts.

A team led by Kuris and Kevin Lafferty is assessing the prospects for introducing a rhizocephalan barnacle, *Sacculina carcini*, that parasitizes *C. maenas* in Europe, its native range. This species blocks moulting of its host, and acts as a parasitic castrator, causing female sterility and feminizing the males. However, genetic work has shown that putative *S. carcini* from several portunid crab genera in Europe cannot be distinguished genetically, (while they are genetically distinct from other *Sacculina* species). Host specificity will obviously be an important issue when other portunid crabs are present in the proposed release area. Techniques are being developed to assess experimentally the host specificity, and its safety for native crabs, and the host-parasite population dynamics are being modelled to help evaluate the conditions under which such a natural enemy might be effective. Fortunately, also, the rhizocephalan's life history is such that adding this parasite to a new area could be reversible. Only the female parasitizes and grows in the crab, forming the interna. Unless a second release of parasite larvae is made after females from the first release have ruptured the abdominal wall of the crab and formed the rounded sac, or externa, containing the reproductive organs and brood sac of the parasite, there is no potential for fertilization, and the parasite population would wither away.

Slugging It Out

The algal species *Caulerpa taxifolia*, found in tropical and subtropical seas, is much prized by aquarium owners as a decorative addition to their tanks. It is a neat plant not exceeding 25 cm in height in its native range. However, a novel form of the species spreading through the Mediterranean would soon outgrow the largest aquarium: dense mats of giant stolons produce tangled masses of fronds up to 80 cm in height. Not only is it vigorous and invasive, but it colonizes the seabed from the shoreline down to 100 m depth, and can give 100% cover of the seabed down to 50 m. It thrives in both clean and polluted water, in exposed and sheltered sites, grows on rocks, sand and silt, clogs the native seagrass beds, and survives far colder temperatures than the conventional form would survive. Another peculiarity: unlike the conventional form, no sexual reproduction has been observed in the Mediterranean weed. Instead it reproduces vegetatively, spreading by fragmentation. These oddities of growth and form have led some to speculate that it is a particular strain, while recent evidence from genetic studies supports the view that it is an aquarium escapee, a clone of a single plant.

But whatever its true identity, the weed is having a serious impact as it spreads relentlessly through the Mediterranean, its thick carpet smothering native algae. It contains toxins (the terpene caulerpenyn) and is not fed on by fish or invertebrates. First spotted covering an area of no more than a square metre in front of the museum aquarium in Monaco in 1984, by 1990 it had reached France, two years later it had reached Majorca, and a year later Sicily. By 1994 it was found growing in the Croatian Adriatic. In 1998 it was acknowledged to be out of control. Mechanical and chemical strategies have been considered but found to be too expensive or too toxic. The weed's growth characteristics also make mechanical attempts at control almost doomed to failure: an attempt to eradicate a colony a week after it was found in the Balearic Islands in 1992 failed, and the plant was flourishing there in 1995. So now scientists are looking at biological control.

Interest is centering on particular seaslugs from the sacoglossan mollusc group, which feed only on the algal order Caulerpales. The coevolution of these seaslugs and the siphonaceous (without cells) Caulerpales has focused on three anatomical and physiological adaptations. Firstly, the slugs do not eat the *Caulerpa*, but feed suctorially on the cell sap, and their digestion is adapted to this fluid diet. Secondly, they accumulate the toxins of the algae to make themselves less palatable to predators. Thirdly, they retain the chloroplasts alive (as symbiotic chloroplasts). The seaslugs utilize these when they cannot find rare *Caulerpa* in the tropical ocean – the chloroplasts are 'actioned' like batteries, so the seaslugs can produce their own food by photosynthesis.

The potential of seaslugs for controlling *Caulerpa* was originally suggested to Alexandre Meinesz of the University of Nice–Sophia Antipolis in France by Kerry Clark of the Florida Institute of Technology in Melbourne, who died in January this year. There are three sacoglossan seaslugs native to the Mediterranean that feed on the local *Caulerpa prolifera.* However, although they have begun to eat *C. taxifolia* also, they may not be effective in controlling it because of their reproductive characteristics. Their eggs hatch into planktonic larvae that disperse widely from where they hatch. However, Meinesz' interest was rekindled when he received a shipment from the Caribbean of *C. taxifolia* that had been partially eaten in transit by individuals of two seaslug species, *Oxynoe azuropunctata* and *Elysia subornata*. Two attributes of these tropical sacoglossan seaslugs are particularly significant: they reproduce fast (1000 eggs/week) and the planktonic larval stage is absent.

Give the climatic differences, it is unlikely that the Caribbean slugs would be able to survive the Mediterranean winter, yet this could be turned to initial advantage. Using an inundative approach, they could be released as 'reversible' biocontrol agents, with augmentation each season. But if they proved successful, there may just be a more permanent solution. There are colonies of the seaslugs living as far north as Florida that are far more cold tolerant, and aquarium tests have been conducted since 1994 to assess their potential as biocontrol agents for *Caulerpa.*

Anchovy Taste

Another significant alien sea invasion of recent decades was that of comb jellies, or ctenophores, to the Black Sea. Native to salty and brackish coastal areas of the western Atlantic, *Mnemiopsis leidyi* was first identified from the Black Sea in 1982. Populations grew dramatically from then, at the same time as marked decreases (90%) in zooplankton biomass were recorded. The Black Sea's largest surviving fishing industry, anchovies, crashed in 1989, when catches fell by more than two-thirds to less than 100,000 tonnes. It is suggested that the unregulated and competing fisheries of Turkey and Russia precipitated the decline, with the comb jellies compounding the problem. Voraciously predatory animals, *Mnemiopsis* devour anything smaller than themselves, but they are more likely to have outcompeted the anchovies for food rather than caused their decline by direct predation. Anchovy stocks have rebounded since then – but arguably because the Russian fleet has been too impoverished to fish.

Biocontrol prospects initially centered on four candidates, all predators: another comb jelly, *Beroe* spp. that specializes in eating other comb jellies, and three non-native fish species that include gelatinous organisms in their diet. However, the terrestrial biocontrol experience with generalist vertebrate predators indicates that extreme caution would be needed before introducing any non-native fish species that could eat native species as well as the introduced pest. Moreover, there were strong arguments against introducing predators to the Black Sea that might migrate into the Mediterranean and compete with native species there. There is one fish species, *Stromateus fiatola,* native to the Mediterranean but absent from the Black Sea, that both eats gelatinous zooplankton and is a valued foodfish. But the efficacy of a relatively slow growing fish predator in controlling populations of *Mnemiopsis,* which dramatically increase in size over a short time, has not been examined.

So far there has been no systematic search for natural enemies of *Mnemiopsis* over its native range. Parasites, parasitoid-like consumers and parasitic castrators are all possibilities – and would be easy to survey for, as the hosts are transparent. However, surveys for pathogens in its native and adventive ranges are now being undertaken. A collaborative project between the University of Delaware College of Marine Studies and the Middle East Technical University Institute of Marine Sciences in Turkey is looking at bacteria from *Mnemiopsis* in the Black Sea and the Atlantic to try and identify any with potential as biocontrol agents.

Catching Crabs and Seastars

In Australia, it has been suggested that marine pests may do as much damage to marine environments as oil spills. In 1997, 172 alien marine species were known to occur in Australian coastal waters, with probably another one arriving each month. Australia now has mandatory reporting of ballast water exchange for incoming vessels and is developing a decision support system to target those vessels most likely to be carrying exotics that would be viable in the port of call. Methods for treating ballast water to slow the rate of new introductions are being tested and a national system for notifying each invasion is in place. Tasmanian marine farmers have started to trap marine pests at their farms and in adjacent unmodified areas, in a new programme, funded by Australia's Coasts and Clean Seas Program. This programme will provide data to the scientists developing control methods, and raise the awareness of marine pests within the industry so that farm practices can be modified to reduce the spread of pests to new areas. Measures to control established alien species – or at least to contain numbers and infestations if eradication is not possible – are being developed. These include genetic manipulation of reproduction, physical removal, targeted herbicides and biocontrol.

Seven marine species are now recognized as pests around the coast of Tasmania, and biocontrol of two of these, the northern Pacific seastar (*Asterias amurensis*) and the European green crab, is being investigated by the CSIRO Centre for Research on Introduced Marine Pests (CRIMP), in collaboration with scientists in Japan, Russia, Europe and the USA. This represents the first coherent programme anywhere in the world to tackle the problem of invasive marine pests and seek control strategies.

The seastar, common in the seas around Russia and Japan, and extending south to Korea and east to Alaska, was probably introduced to Australia in the early 1980s, and was recorded until last year only in the Derwent estuary, site of Tasmania's major port. Nic Bax of CRIMP says that its spread from the Derwent is believed to have been restricted by the estuarine circulation, but it has recently been found in Victoria's major port, Prince Phillip Bay. Genetic tests indicate that this introduction was most likely through the Tasmanian population, the probable vector – shipping. The seastar feeds voraciously and omnivorously on shellfish, and virtually all sizeable bivalves and other attached or sedentary invertebrates are eliminated where seastar densities are high. This may not only affect the biodiversity, but also have effects on the ecosystems of which bivalve filter-feeders are a key component. One possible and highly undesirable impact would be the possible extinction of the unique and beautiful little handfish, which, unusually for marine organisms, have localized geographical distributions. Females lay eggs, which the males guard, on attached invertebrates such as sea squirts where the seastar can eat them. The seastar threatens the fisheries of southern Australia – even in its native range it has a significant impact on fish and shellfish productivity. It has wide temperature and salinity tolerances, and populations in the Derwent estuary have grown to the point where it is the dominant invertebrate predator of some benthic communities. Population densities easily exceed those recorded in its native range – one estimate puts the Derwent Estuary population at 30 million. Its impact is considered so significant that ports in Tasmania, and now Port Phillip Bay, are the only ports in the world from which ships are prevented from releasing ballast water in New Zealand's coastal waters under any conditions.

Physical removal of seastars using divers or traps has been trialled. Community divers removed 30,000 seastars from around the Hobart wharves on two occasions in 1993, or perhaps 60% of the animals from an area that is a fraction of the occupied area. Traps provide a more cost-effective alternative to control chronic infestations, but at low densities attract seastars in from outside the area. Dredges and trawls have been used in Japan to control the seastar prior to seeding an area for shellfish aquaculture, but associated environmental damage would be excessive in an unfished area. Non-specific chemicals, principally quicklime, have been used to locally control seastars on shellfish beds, but collateral damage is high.

Non-specific physical and chemical control may have a role in local control of seastars around aquaculture farms, but Bax points out that control of the seastar population will require a highly specific control agent that can be widely dispersed throughout the population. Specific predators have not been found, although one larger native seastar does eat *Asterias* in laboratory situations.

Potential parasites for biocontrol have been sought in Japan and Russia, in collaboration with the US team led by Kuris and Lafferty. From hundreds of seastars sampled during the first survey in Japan, a single specimen, from the far-eastern arm of Hokkaido was found to be infected with a ciliate parasite. A second survey during the peak reproductive season found the ciliate to be abundant and widespread. So far this species, the scuticociliate *Orchitophrya stellarum,* is the only one to show promise. It partially castrates *Asterias* in its native range, and is associated with mortalities of another seastar. Genetic tests are unable to distinguish *O. stellarum* found in several *Asterias* species and another asteroid, suggesting host specificity may be low. However, as only a single asteroid species appears to be parasitized by *O. stellarum* in any one geographic area, there may be morphological or ecological attributes that increase host specificity. CRIMP is now extending the search for suitable parasites to Korea, in the hope that additional parasites, perhaps dendrogastrids (highly modified intracoelomic seastar parasites), may be found at the limit of *Asterias'* range. A separate research approach is to find highly specific reproductive inhibitors – asterosaponins are reported to be species-specific regulators of gamete release – that can be introduced into the environment perhaps via transgenic manipulation of a prey resource, but this research is in its infancy.

The European green crab was first recorded in southern Australian waters (Port Phillip Bay) in 1902 and is now an accepted part of the fauna in Victoria. In the mid-1970s the crab was first reported in South Australia, where its range may be continuing to expand. In 1993, it was first reported in Tasmania, where it is now extending its distribution along the north and east coasts, displacing native crabs and potentially decimating native bivalves. In 1997, CRIMP sponsored an international conference on the demography, impacts and management of the European green crab, which served to bring together researchers from the USA and Europe. Prospects for biocontrol using the rhizocephalan barnacle *Sacculina carcini* are not as promising in Tasmania as the USA, as native portunid crab species that are the basis of developing fisheries could also be vulnerable to the parasite, but testing of host specificity is ongoing. However, populations of the green crab in Victoria appear to be controlled by natural factors – predators, competitors or reproductive failure – and research is in progress to establish the nature and management potential of these controls.

Water Safety

Work on the projects described above is still at an early stage, and whether any or all of this leads to attempts at biological control remains to be seen. But one aspect that all participants are addressing seriously is safety. By the time this article appears, this aspect will have been under discussion at the 1st Conference on Marine Pest Bioinvasions at the Massachusetts Institute of Technology, USA in January 1999. As in terrestrial biocontrol, host specificity is a key issue. Bax points out that in the marine environment pest management and, therefore, the development of biocontrol programmes are driven as much by concerns for biodiversity as food production. With the advantage of more than a hundred years of terrestrial biocontrol to draw on, marine biocontrollers hope to avoid some of the pitfalls that were encountered on land, including damage to native populations.

Kuris says that the strategy being developed for marine biocontrol is modelled on the traditional agricultural biocontrol strategy, i.e. natural enemies are sought in the native range of the pest, then assessments are made of the efficacy and safety of putative agents. But, he argues, although the strategy is similar, the problems differ. Whereas insect pest biocontrol, to be economically viable for food production, must sometimes reduce pest abundance by more than 99%, marine pests need only be reduced by half or two-thirds to have a tremendously beneficial outcome for biodiversity. Kuris suggests that the intellectual challenge for marine pest biocontrol arises from the very different recruitment systems of marine and terrestrial systems. On land, recruitment is relatively closed: kill the scale in an orchard today and you greatly reduce recruitment of scale to those trees tomorrow. But kill the barnacles on a rock today and you have had no impact on recruitment tomorrow – because of relatively long-distance larval dispersal and consequent open recruitment. So the emphasis on marine biodiversity requires control measures to be targeted at the long-term control of the pest population, rather than the seasonal control that is satisfactory for many terrestrial agricultural biocontrol situations. Thus, classical biocontrol may be a fundamental long-term strategy for marine systems.

Although biocontrol may seem an attractive answer, there is understandable reluctance from marine resource managers to contemplate release of biocontrol agents in the open marine environment. Yet, as the impacts of marine pests increase, affecting increasingly charismatic or edible megafauna, it is clear that action will be necessary. Bax suggests, however, that initial results indicate that it may not be sufficient, except in isolated instances, to rely solely on the introduction of natural predators and parasites to control populations of marine pests. He cites delivery of species-specific regulatory chemicals through genetic manipulation of parasites, symbionts, predators or prey as providing one promising area of research.

Further reading: Lafferty, K.D.; Kuris, A.M. (1996) Biological control of marine pests. *Ecology* **77**, 1989-2000.
Meinesz, A. [*trs* D. Simberloff] (in press) Killer alga. Chicago, USA; Chicago University Press. 352 pp [estimate]. ISBN 0 22 651922 8. Estimated price: US$25.00. Due September 1999.

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Global Invasive Species Programme

Introduced species cause disasters that one would never have foreseen. The costs of Eurasian zebra mussels, introduced into the Great Lakes system of North America where they cause obstruction in pipes and locks, are estimated to be hundreds of millions of dollars annually. Leafy spurge, a poisonous plant from Europe, invaded western rangeland in the USA and caused losses of more than US$100 million per annum. The Nile perch, introduced into Lake Victoria to improve fishery, caused the extinction of more than 100 fish species of the cichlid family; most of them endemic to the lake – before the predator came it was called an evolutionary laboratory. Feral mammals introduced to islands have brought many bird species to the brink of extinction or beyond by feeding on their eggs and chicks. These are just a few examples where action was taken too late.

Past responses to invasive problems generally have been crisis-orientated and undertaken by scientists and government officials. The new Global Invasive Species Programme (GISP) is adopting an interdisciplinary, proactive approach to prevention and management. Economists, geographers, trade experts, and international environmental policy specialists – in addition to scientists, managers and government officials with expertise – will contribute to the development and promotion of a practical, comprehensive strategy to turn the tide against harmful invasive species worldwide.

GISP is co-ordinated by SCOPE, the Scientific Committee on Problems of the Environment, in conjunction with IUCN (International Union for Conservation of Nature and Natural Resources), CAB International and UNEP (UN Environment Programme). Initial financial support comes from the Global Environment Facility (GEF), UNEP (UN Environment Programme), UNESCO (UN Educational, Scientific and Cultural Organisation), the Norwegian Government, NASA (US National Aeronautical and Space Administration), ICSU (International Council of Scientific Unions), La Fondation Total, and the John D. and Catherine T. MacArthur Foundation, together with 'in-kind' contributions from its participants.

Introduction of organisms into new environments has always been part of human history since humans began to travel and spread over the continents, but in the past century human movement accelerated and thereby enhanced dramatically the number of species introduced to continents and islands. The problems of alien invasives are likely to become even more severe in future with increasing global trade and travel. Agricultural weeds, destructive insects and mammals, diseases and other organisms exhibit a wide set of negative impacts on economic productivity, ecological stability, biodiversity and human health on a global scale. The dispersal of organisms by human means can be accidental or intentional. In general, these introductions are characterized by faster invasion than natural occurring self-introductions. Examples of accidental introductions are hitchhikers on substrates of trade items, terrestrial organisms on aeroplanes and ships, aquatic organisms in the ballast water of ships [see 'Aliens Make Waves', this issue], and parasites and disease organisms brought in with authorized introductions. Deliberate introductions have been made for a variety of purposes, such as changes in agricultural techniques, forestry, supply for hunting and fishing, or ornamental reasons. Many of those species are beneficial, or may be neither useful nor harmful, but increasing numbers of them are recognized as harmful invasive species.

Information about prevention and management of alien invasive species is limited and scattered. Furthermore, effective action against alien invasive pest problems requires global co-operation, since the spread of invasives does not stop at borders, and international legislation is needed to tackle the problems caused. GISP has, as its objective, to assemble and share the best available information on alien invasive species and to stimulate needed action and research. It is composed of 11 parts: the human dimension, invasion ecology, pathways, global change, risk assessment, economics, status assessment, legal aspects, education, early warning systems, and management.

The early warning part, co-ordinated by Dr Mick Clout (IUCN, Invasive Species Specialist Group), and the management part, under responsibility of Dr Jeff Waage (CABI Bioscience, Biological Pest Management), will unite their efforts in a shared expert consultation, to be held at the end of March 1999 in Kuala Lumpur, Malaysia. The objectives will be to design useful early warning systems and a supporting database, and to identify the key elements of a useful manual ('toolkit') for alien invasive species management and prevention. Participants in the consultation will include experts in key disciplines and knowledgeable government representatives from client countries with either experience or needs in alien invasive species prevention and management programmes.

GEF is providing support for GISP to develop pilot early warning systems for prevention of invasive alien species introductions, and to develop toolkits for governments on prevention and management. Both initiatives will address particularly the needs of developing countries. These validation projects will have their major focus on Small Island Developing States (SIDS) in the Pacific and Indian Ocean regions, since island ecosystems are especially vulnerable to invasions.

We need to act locally and think globally to stop the invasions into ecosystems, the loss of biodiversity, and the macdonaldization of the world by aggressive invasive organisms.

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Green Muscle® Registered in South Africa

Green Muscle®, the mycoinsecticide for locust control based on an oil formulation of the fungus *Metarhizium* [see *BNI* **18(2)**, 23N], was successfully registered for sale in South Africa in November 1998. Developed over nine years by the LUBILOSA (LUtte BIologique contre les LOcustes et SAuteriaux) international research programme, the mycoinsecticide is specific to locusts, leaving other non-target organisms unharmed.

Green Muscle® is the first environmentally friendly, non-chemical insecticide to be registered for locust control and the registration in South Africa is a significant step in moving the locust pest control strategy away from the use of persistent, non-specific and sometimes harmful chemicals towards more sustainable control strategies incorporating biological control techniques. Green Muscle® has already been recommended for use in environmentally sensitive areas by the Locust Pesticides Referee Group of the Food and Agriculture Organization of the UN and the approval for sale by the South African authorities is further confirmation that Green Muscle® is a safe, effective and desirable method of locust control.

The product will be made by Biological Control Products in Durban and is expected to be on the market in 1999. The LUBILOSA programme is also seeking registration of Green Muscle® in West African countries in collaboration with a second commercial producer.

LUBILOSA is an international collaborative research and implementation programme which is led by CABI Bioscience in collaboration with IITA (International Institute of Tropical Agriculture, Benin), CILSS (Comité Inter-Etats pour la Lutte contre la Secheresse dans le Sahel, Mali) and GTZ (Deutsch Gesellschaft für Technische Zusammenarbeit, Germany), and funded by development agencies in UK (DfID), Canada (CIDA), Netherlands (NEDA) and Switzerland (SDC).

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Prickly Problems in Australia

Here we include reports on major biological control initiatives against two leguminous weeds that are causing significant problems in two entirely different ecosystems in Australia. A third leguminous weed, *Parkinsonia*, will be dealt with in a future issue.

Preventing Wetland Wipe-out

Mimosa pigra (giant sensitive plant, or 'mimosa') is a prickly leguminous shrub that is currently overwhelming wetland habitats in the monsoonal area of the Northern Territory. At particular risk is the World Heritage conservation area of Kakadu National Park, although mimosa also impacts on the pastoral, tourism and recreational fishing industries. Introduced during the nineteenth century from the Neotropics, where it is a relatively inconspicuous plant of river banks and marshes, mimosa started to spread rapidly in the 1970s following several years of above-average rainfall, aided by the heavy impact of feral Asiatic water buffalo. It now infests some 80,000 ha of floodplains in several Northern Territory river systems, forming impenetrable thickets growing up to 6 m high and suppressing native vegetation beneath the canopy. The plant produces thousands of seeds per square metre every year. Their water-borne dispersal is enhanced by bristles on the seedpods, which keep them afloat and allow them to be dispersed over vast distances. Seeds are also dispersed by birds, livestock, and native and feral mammals. Mimosa has been described as the largest single environmental threat to Northern Territory's wetlands, and has the potential to spread further, into Western Australia and as far south as New South Wales. Over the last two decades, a collaborative programme between CSIRO Entomology and the Northern Territory Department of Primary Industry and Fisheries (DPIF) has been developed to implement biological control of mimosa. CSIRO Entomology has undertaken exploratory work in Mexico, Central America and South America, to identify natural enemies with potential as biological control agents. Promising insect species have been tested in the CSIRO Entomology quarantine facilities in Brisbane, and those species considered safe to release have been mass-reared and distributed by DPIF staff in the Northern Territory.

So far nine insect species and two fungal pathogens have been released, and to date the most successful of these have been the flower-feeding weevil *Coelocephalapion pigrae*, and the stem-boring moths *Carmenta mimosa* and *Neurostrota gunniella.* Recent emphasis has been on the testing and introduction of seed-feeding weevils, with *Chalcodermus serripes* being first released in 1996 and *Sibina fastigiata* in 1997. DPIF and CSIRO staff in Darwin are currently involved in monitoring the distribution and abundance of all agents, as well as undertaking experiments to determine their impact on the growth and productivity of mimosa.

Two fungal pathogens from Mexico were collected and screened at IIBC (now CABI Bioscience) by staff from CABI, the Instituto de Ecologia in Xalapa and the CSIRO station in Veracruz, and these have also been introduced into Australia. The coelomycete *Phloeospora mimosae-pigrae* is active during the wet season and causes stem cankers and die-back of the weed in its native range. It was first released in Australia in the wet season of 1994 and has subsequently established. Since then DPIF and CSIRO have developed mass rearing methods and procedures for large-scale releases by helicopter. In 1998 five isolates of *P. mimosae-pigrae* from different locations in Central and South America were brought into Australia, and DPIF is currently investigating genetic variations between these and the original isolate from Mexico. Pathogenicity tests will identify the most suitable isolate for the Northern Territory. The leaf rust *Diabole cubensis* requires the lower temperatures of the dry season (~21^{o}C) to establish, and was first released in 1996. During the wet season, the rust is cultured under shadehouse conditions and the spores stored in liquid nitrogen for release the following wet season. The rust has established locally, and DPIF has commenced a monitoring programme.

In its new home on the Northern Territory floodplains, mimosa is an extremely vigorous and successful invader. Although current thinking is that biological control is the best long-term option for management of this weed, other techniques are available for its control, including herbicide application, bulldozing and burning. It is likely that use of these other techniques will be required in many areas to reduce the size and vigour of stands to enable biological control to become effective more rapidly. Research is underway to develop a sustainable management strategy for mimosa, based on integration of available control options. Biological control is likely to be the long-term cornerstone of successful management.

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...and Beating Mesquite

Mesquites (*Prosopis* species) are woody, leguminous shrubs or trees that are extremely well adapted to growing in semi-arid and arid regions, often thriving in extremely arid, saline and inhospitable locations where no native trees can survive. They are valued by many as a multi-purpose resource, as shade, wind-breaks and fodder, and for human consumption, charcoal, timber and land reclamation. The ability of some species to rapidly form impenetrable and intractable thickets has, however, resulted in some mesquite species transforming vast tracts of open rangelands into thorny shrub forests. Negative impacts include the replacement of native flora and fauna, the reduction of stock-carrying capacity through pasture replacement (stocking rates in New Mexico were reduced by 75% over a 45 year period), impeding the management of livestock, and harbouring feral animals[1]. As a consequence mesquites have become major pastoral and environmental weeds in many regions of the world, including within their native range. In the USA, mesquite causes an estimated loss of US$600-1500 million (1984 figures) to the livestock and support industries[1].

In Australia *Prosopis* is a declared noxious weed, and is regarded as a serious economic and environmental threat. The taxonomy of Australian *Prosopis* is still unresolved, but there are at least five taxa currently recognized to have become naturalized. These species are native to the Americas but differ in their ecology, particularly with respect to their potential distribution, aggressiveness as weeds and fire tolerance. Infestations are presently localized and still in the early phases of invasion. They occur in all mainland states, with the largest patches of dense infestations occurring in Western Australia (>20,000 ha) and Queensland (several patches >3000 ha). There do not appear to be any climatic or geographic limitations to the spread of mesquite over much of semi-arid Australia.

Eradication programmes have been conducted in various regions of Australia since the late 1960s and rely primarily on chemical and mechanical methods. The hardiness of mesquite, together with its extensive rooting system, high seed production, efficient seed-dispersal and a long-lived seed bank, mean such programmes are costly and necessarily long term. In addition infestations typically occur in remote, commercially low-value regions. To date no significant populations have been successfully eradicated, although a major eradication programme is currently underway in Queensland.

CSIRO Entomology began research into the biocontrol of mesquite in 1994. This work involved reviewing the mesquite problem in Australia (the extent of the problem, the history and success of control programmes, and a review of taxonomic and ecological aspects) and prioritizing and processing potential biocontrol agents. Previous biocontrol programmes directed against mesquite had already resulted in the release of seed-feeding bruchids in South Africa, and later in Australia, but recent studies have shown that the impact of these agents is likely to be limited by vertebrate herbivory. *Prosopis* seeds are primarily dispersed through the gut of vertebrate herbivores, which consume most pods before bruchids have the opportunity to damage the seeds.

The CSIRO programme selected insect species for host-specificity studies which targeted vegetative foliage and reproductives prior to their consumption by vertebrate herbivores, and which appeared to be impacting on mesquites in their native range. Three potential agents were studied: a coreid bug (*Mozena obtusa*) which feeds on immature reproductives and vegetative foliage, a sap-sucking psyllid (*Prosopidopsylla flava*) which causes die-back, and a leaf-tying gelechiid moth (*Evippe* sp. #1) which is a defoliator. Only the latter two species were specific to mesquite and permission was obtained to release them in Australia. Both are from Argentina where the Australian mesquite taxa do not occur, but perform equally well on these, at least in the laboratory. An Australia-wide release programme is now underway with multiple releases of each being made at 24 sites in four states. The leaf-tier has been released since March 1998 and field populations have already been recorded at some sites. The psyllid has been released since November 1998.

Both new agents attack vegetative foliage and have the potential to make a significant impact on mesquite populations. Specifically, they have the potential to retard the expansion and thickening of mesquite populations by increasing mortality rates of seedlings and juveniles, slowing development from germination to maturity, and decreasing pod production of mature plants. Where eradication is the goal it is hoped that these new agents will complement existing control options such as mechanical and chemical treatments, by hitting regrowth and surviving plants, possibly decreasing the number of treatments required until the seed bank is exhausted.

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Coconut Whitefly in Nevis

Several species of whiteflies belonging to the genus *Aleurodicus* have recently become pests of economic importance, mainly by accidental introduction into new regions. Among them are *Aleurodicus dispersus* in several West African countries, *Aleurodicus dugesii* in the United States, *Aleurodicus cocois* in Peru and *Aleurodicus pulvinatus* in Nevis. Since chemical control of these species is difficult and uneconomical, biological control using host-specific natural enemies offers the most sustainable long-term solution.

Most members of the sub-family Aleurodicinae, to which *Aleurodicus* belongs, are restricted to the Neotropics (Central and South America, subtropical North America and the Caribbean). They are generally larger in size than the better-known whiteflies, such as *Bemisia tabaci* and *Trialeurodes vaporariorium*, with a wing span of more than 3.5-4 mm. Many species of *Aleurodicus* typically lay their eggs in spirals. However, the common name 'spiralling whitefly' applies only to *A. dispersus*. In their native habitats, a wide range of natural enemies usually keeps *Aleurodicus* spp. in check, e.g. in Trinidad several predators and parasitic wasps provide effective control.

Aleurodicus pulvinatus has recently become a serious pest of coconuts in Nevis. It was initially believed to be *A. cocois.* However, following surveys by CABI consultants (M. Cock & G. Watson) in 1995, the species was tentatively identified as ?*Aleurodicus iridescens.* A further taxonomic comparison with material originating from the region clarified the identity of the species from Nevis, and *A. iridescens* was synonymized with *A. pulvinatus*. Although several natural enemies were found attacking *A. pulvinatus* in Nevis, none was effective in controlling it. A project was therefore undertaken at CABI Bioscience Caribbean and Latin American Centre in August 1996 to identify and select appropriate parasitoid species attacking *A. pulvinatus* in its native range for introduction into Nevis. The project was funded by the Food and Agriculture Organization of the UN (FAO) under a Technical Cooperation Project (TCP/STK/4551).

Extensive surveys in Trinidad and Tobago revealed the presence of *A. pulvinatus* and several *Aleurodicus* spp. They were attacked by a host of natural enemies including parasitoids and predators, particularly coccinellids belonging to the genus *Nephaspis.* Of five parasitic species recorded, two aphelinid species, *Encarsiella* sp. D and *Encarsiella noyesi,* were chosen for introduction into Nevis. Techniques for culturing *Aleurodicus* spp. and the two parasitoids were developed.

Although the two species often occurred together under natural conditions, *Encarsiella* sp. D was the predominant species and was hence prioritized for introduction. Dossiers were prepared in line with the Code of Conduct for the Import and Release of Exotic Biological Control Agents and submitted to the Department of Agriculture in Nevis. Because of possible competition between *Encarsiella* sp. D and *E. noyesi*, the introduction of the latter species was deferred until a proper assessment of the establishment and impact of *Encarsiella* sp. D could be done.

Following approval of the introduction, the first shipment of *Encarsiella* sp. D was hand-carried by Moses Kairo who also trained the officers of the Department of Agriculture in field release and assessment techniques. A total of over 2500 parasitoids were shipped during April and May. In mid-September, the species was recovered at several release sites and was found to have dispersed up to about a kilometre from the nearest release site. Thus, there is good evidence that *Encarsiella* sp. D will become established and the prospects for a successful control of *A. pulvinatus* in Nevis are promising.

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Tsetse's Lethal Path

Tsetse flies (*Glossina* species) infest some ten million square kilometres of sub-Saharan Africa. They are important as vectors of human sleeping sickness and 'nagana' disease in livestock and determine, to a large extent, where rural African communities can profitably live and work.

The major efforts to control tsetse over the past decades range from destruction of vegetation and/or eradicating their wild hosts to widespread application of chemical insecticides. More recently, less environmentally harmful methods have been developed such as the attraction of flies to traps ('trap and kill') or targets that have been treated with insecticides or a sticky substance, or the use of low-volume pour-on insecticides for treatment of cattle thought to be at risk. The sterile insect technique (SIT) has recently been successfully used to eradicate tsetse flies from the island of Zanzibar [see *BNI* **18(4)**, 107N-108N] and is being tested for mainland eradication in Ethiopia.

No single method of tsetse control has thus far proven to be satisfactory. This is partly due to biological factors (residual populations of flies remain and re-invade the cleared zones[1] and not all species respond equally to the same control method) and partly to socioeconomic reasons such as long-term financing and community involvement. For instance, SIT eradication programmes have proven to be very expensive (US$18 million for tsetse in Zanzibar; US$75 million for screwworm in Libya[2]). Use of insecticidal targets and pour-ons are cheaper in the short term, but are environmentally hazardous.

This report briefly describes some options for tsetse fly management being developed by the Nairobi-based International Centre of Insect Physiology and Ecology (ICIPE), using a local strain of the entomopathogenic fungus, *Metarhizium anisopliae*. These activities are part of an Austrian Development Cooperation- (ADC-) funded project on 'Sustainable Management of Trypanosomosis and Tsetse Flies through a New Concept: the Lethal Insect Technique (LIT)' being implemented in Kenya.

Although entomopathogenic fungi have been reported to infect tsetse flies in the laboratory, the major obstacle to their use has been the difficulty of application in the field. ICIPE's efforts to address this problem were first made under the project on 'Interactive Development and Application of Sustainable Tsetse Management Technologies for Agropastoral Communities in Africa', funded by the European Union (EU) from 1993-1995. Several potential biological control agents were evaluated. To make the existing models of tsetse trap even more effective, a contamination device (Cd) was developed for use with the standard traps, such that captured flies passing through the Cds mounted on the trap apex are contaminated with fungal conidia before they return to the environment and transmit conidia to healthy flies during mating or other interactions including brief bodily contacts[3].

An important first step of the current ADC-funded LIT project was to reactivate interest and support for the Cd system along with a new approach that relies on the use of cheap, insectary-reared male and female flies as vehicles to transmit entomopathogenic fungi directly from 'donor' to 'recipient' individuals (D. J. Nadel, unpublished). With the new concept, both sexes can be effectively released to serve as carriers of the pathogen. The Cd itself is made of the ubiquitous locally available plastic mineral water bottles and has been improved and optimized for use under all weather conditions (N. K. Maniania, unpublished). Its performance has been tested under field conditions and results indicate that although conidia of *M. anisopliae* may lose a fifth to a third of their viability after 31 days, this does not affect the overall fly mortality caused by fungus.

The success of the project relies on the ability of contaminated male or female 'donors' to transmit fungal conidia to healthy 'recipients'. Laboratory studies have shown that a single fungus-contaminated male or female tsetse fly can transmit *M. anisopliae* conidia to at least four other flies during mating or other brief interactions[4]. Field trials are under way to test the Cd system on *Glossina fuscipes fuscipes*, a vector of both human sleeping sickness and nagana on several small- to medium-sized islands in Lake Victoria off ICIPE's Mbita Point Field Station. Conidia of *M. anisopliae* are being mass-produced at ICIPE on a simple substrate of ground maize and vermiculite contained in plastic buckets wrapped in polyethylene bags. The Cds are loaded with a few grams of dry conidia and mounted on the appropriate traps. The conidia are renewed monthly. The results so far are promising. A high proportion of flies captured from the test areas has shown fungal infection on the surface of cadavers.

A cost-effective, simplified, semi-automated mass-rearing system has been developed for rearing tsetse for field tests.

Tsetse has long been a major constraint to development for many sub-Saharan African countries. If the results promised by this research are fulfilled, the tsetse challenge to humans and livestock in Africa could be significantly reduced, at an affordable cost.

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Brazilian Nematode Castrates House Flies

Until recently, the only known natural nematode parasites of the house fly were parasites of mammals that use the fly as an intermediate host such as *Habronema* spp. In the late 1970s Reginald Coler isolated an unknown parasite infecting small numbers of house flies in Brazil. This nematode, which is native to the state of Pernambuco, was subsequently reisolated and described as *Paraiotonchium muscadomesticae*[1,2].

Nematodes in the genus *Paraiotonchium* are parasites of muscid flies, and the group includes several species that were in the genus *Heterotylenchus* prior to Slobodyanyuk's revision[3]. The best-known member of the genus is *Paraiotonchium autumnalis*, a parasite of the face fly (*Musca autumnalis*)[4]. Other muscids with parasites in this genus include *Morellia simplex* (*Paraiotonchium simplex*), *Musca vetustissima* (*Paraiotonchium nicholasi*), *Musca osiris* (*Paraiotonchium osiris*), *Musca xanthomelas* (*Paraiotonchium xanthomelas*), and *Musca crassirostris* (*Paraiotonchium crassirostris).* Coler[1,2] has recently reviewed the taxonomic status of this group of parasites.

The life cycle of *P. muscadomesticae* is an interesting one that includes parasitic castration and mock oviposition. Flies are infected in the larval stage when mated female nematodes penetrate the host's larval cuticle. These females deposit eggs in the haemocoel of the adult fly, producing a generation of parthenogenetic females. The parthenogenetic females then produce a generation of gamogenetic nematodes that invade the ovaries of female flies. The flies perceive themselves to be gravid and attempt to oviposit, depositing young male and female gamogenetic nematodes instead of eggs. Infected flies are thus essentially castrated and deposit few, if any, healthy eggs. After being deposited by the fly, the nematodes mate and female parasites search for new hosts to invade. Although male flies also are infected, the effect of the nematode on males and the role of infected males in the nematode's life cycle are unknown.

Recent research indicates that this species may be an attractive classical biological control agent for house flies[5]. Infected adult flies of both sexes live for about half as long as healthy flies, and produce almost no progeny. When house fly immatures are exposed to nematodes from infected flies, an IC_{50} (the nematode concentration needed to infect half of the flies) of only 24 gamogenetic nematodes/fly is observed, with an IC_{90} of 184. Mature gamogenetic female nematodes produce about eight parthenogenetic females each, regardless of nematode crowding levels. In contrast, production of new gamogenetic nematodes by parthenogenetic females is density-dependent, with average reproductive rates ranging from 1627 progeny/parthenogenetic female at eight females/host to 330 progeny at 83 females/host. This density-dependent reproduction ensures that infected flies consistently produce 12,000-45,000 new gamogenetic nematodes, which are ready for deposition about ten days after fly emergence. Gamogenetic nematodes require 24 hours after deposition in manure before they are capable of infecting new host larvae. Nematodes persist in manure for three to five days after deposition. Although the normal habitat of the nematode is not known, laboratory studies indicate that it survives well in cattle and poultry manure.

Host range studies also have demonstrated that this nematode is fairly host specific. Although some infections have been observed in a second pest species (stable flies), *P. muscadomesticae* has little impact on *Hydrotaea aenescens*, a predacious fly that is being used in some fly control programmes. The main challenge in developing this species as a biocontrol agent may be its sensitivity to high temperatures. The nematode performs well up to 30^oC, but not at higher temperatures, and this may limit its survival in areas with very hot weather conditions.

In summary, *P. muscadomesticae* appears to have considerable promise as a classical biological control agent for house flies. Larvae are highly susceptible to infection, resulting either in the death of the larval host or parasitic castration of the adult fly. It is compatible with other fly biocontrol agents, and targets a life stage of the fly (mature larvae) that no other common natural enemies attack. Infected flies can be produced easily in large quantities and could be released on livestock and poultry farms, preferably as seven- to nine-day-old infected flies. If successfully introduced from its native Brazil, this nematode could fill an empty niche in the biology of the house fly and aid in its control.

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Cricket in Australia: the Worms' Turn?

A foreign sort of cricket threatens to undermine the future of the Australian national game – not to mention golf, football and horse racing, Parks and gardens could suffer serious damage, and key crops such as sugarcane and rice are also at risk.

The Changa mole cricket (*Scapteriscus didactylus*), of South American origin, was first reported in Australia in 1984 from Newcastle, New South Wales (NSW). Larger than native crickets, it lives underground by day, coming out at night to feed on leaves of grasses and other crops. Females can lay up to 4500 eggs in a season. It is not a highly mobile pest, although the crickets are winged. Dispersal occurs mostly by movement of infested soil and plants, or by the winged adults being attracted to light, and alighting on transport on which they can also lay eggs.

A species native to warmer climes, this cricket was for some years confined to the Newcastle area, where it took the odd chunk out of golf courses and parks. However, recently it has begun to spread, and this is causing concern because, based on the climate of its home range, it could potentially cover an area from Sydney in NSW to Cairns in Queensland. Moreover, it is currently invading areas theoretically too cold for it to survive, and fears are being expressed about what would happen if it reached its ideal climate range in northern NSW and Queeensland, and key centres of the rice and sugarcane industries there.

So is this really one visitor that might give Australian cricketing enthusiasts something to worry about? Possibly not. Robin Bedding of CSIRO thinks he may have something that could knock it for six. He suggests that a nematode, *Steinernema scapterisci*, which was used against related mole crickets in Florida, may be the answer. He plans to conduct laboratory tests with the nematode and, if the results of these are promising, to seek permission to field test it. It could be a pitch battle.

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Lines from the South Pacific

Taming the Giant

Fiji has reported some success from a joint biocontrol programme for the giant sensitive plant (GSP) *Mimosa invisa* involving the Secretariat of the Pacific Community (SPC) – German Biological Control Project and the Ministry of Agriculture Fisheries and Forests (MAFF). The weed was reported for the first time in the South Pacific region in Queensland early in 1929, and it is now found in at least ten countries in the Pacific region: French Polynesia, New Caledonia, Papua New Guinea, Samoa, the Solomon Islands, Vanuatu, Fiji, Guam, Hawaii and the Cook Islands, and it was reported recently for the first time from the island of Niue. The weed is under control in the Cook Islands following the release of the psyllid *Heteropsylla spinulosa* there in 1994.

In Fiji, a joint programme by MAFF and the SPC–German Biocontrol Project involved the augmentation of the psyllid populations (a redistribution exercise) at major infestation areas on western side of the island of Viti Levu, prior to the new growing season at the onset of the annual rains. The psyllid populations were boosted by spot treatments with nitrogen (as urea), carried out with the assistance of MAFF extension staff at the various centres. Flowering and seed production were reduced by the more abundant psyllid populations, and new growth was thus prevented. The method of boosting psyllid populations was adopted on the basis of the results of a study by Kuniata and Kowiri in Papua New Guinea in 1994. The SPC–German Biological Control Project and Fiji MAFF continue to monitor the situation of the weed in Fiji.

Ladybirds Hit the Scales

Coccinellid predators are being redistributed from Fiji to Nanumaga Island (Tuvalu) in an effort to stem an alarming outbreak of the coconut scale, *Aspidiotus destructor*.

The scale first appeared in the South Pacific region in Tahiti in about 1894, spreading to Fiji in 1905. It was first reported from Vanuatu in 1962 and New Caledonia in 1983. It is now also found in the Cook Islands, Kiribati, Niue, Tokelau, Tonga and Tuvalu. Surveys conducted in Fiji to identify natural enemies present there failed to find *Cryptognatha nodiceps*, but a number of other coccinellid predators were found. However, some of these were proved not to be host-specific to the coconut scale in laboratory trials. The two most effective were *Telsimia nitida* and *Chilocorus nigritus*: they completed their life cycles on the scale, and both larvae and adults fed on it. The biocontrol agents were identified and mass-reared under specific guideline conditions in the laboratory in Suva before onward shipment and release in Nanumaga.

The scale was first recorded in Nanumaga in 1994, where it caused severe damage to important food crops in the atoll; it attacked coconuts, bananas, pawpaws, breadfruit and other food crops in massive numbers causing panic on the island. The SPC Plant Protection Service through its Biological Control Laboratories released the two predatory coccinellids *T. nitida* and *C. nigrita* from Fiji, and these have been instrumental in reducing the pest populations. Impact studies are being conducted to assess the efficacy of these predators, and the prospects for releasing other predators from Fiji are also being considered.

Recently, resurgence of the coconut scale has been reported elsewhere, with serious outbreaks (similar to those in Nanumaga) occurring in Rotuma (Fiji) in the absence of natural enemies. The SPC and the Research Division in Fiji are currently working together to introduce biocontrol agents in Rotuma.

Finally, a new pest of coconut, a hispine beetle (possibly a *Brontispa* sp.), has been reported to be causing damage to coconuts in the Marianas Islands. The identity of this new pest is currently being considered, together with prospects for its biocontrol.

Cabbages and Wings

In the Cook Islands, diamondback moth (DBM), *Plutella xylostella*, is one of the most serious larval pests of cabbages, while the potentially disastrous silverleaf whitefly (*Bemisia tabaci* biotype b/*Bemisia argentifolii*) is also present. An IPM programme on cabbage is being promoted as part of the SPC–German Biocontrol Project collaborating activities with the Cook Islands Ministry of Agriculture. The parasitoid *Diadromus collaris* was released against DBM in Rarotonga in 1998. Mass rearing of the parasitoid is carried out at the Totokoitu Research Station by research staff. Monitoring studies are being conducted on the whitefly and potential biocontrol agents are being assessed. Locally abundant coccinellids, which have been found to have a significant predatory impact on the whitefly, have been sent for identification.

In Fiji, the Cabbage IPM Programme, spearheaded by the SPC–German Biocontrol Project has, since 1995, tried to promote an IPM package recommending the use of two selective insecticides; the bacterial insecticide Delfin and the chitin-inhibiting Atabron. The parasitoids *D. collaris* and *Cotesia plutellae* are also helping to control DBM in major cabbage-growing areas in Fiji.

Beetles Hit

Progress has been also reported with the use of pathogens against two beetle pests. In Fiji, a combination of viral and fungal products and refined management practices has led to a reduction in rhinoceros beetle (*Oryctes rhinoceros*) numbers and associated damage to coconut palms.

Taro beetle (*Papuana* sp.) biocontrol research, centered in the Solomon Islands and Papua New Guinea, has been concentrating on optimizing the conditions for the effective use of the fungal agent *Metarhizium* and a baculovirus, and progress has been made with a bacterial agent, *Bacillus popilliae*. Meanwhile, the search for new pathogens of taro beetle continues, and leaflets describing techniques for handling and assessing microbial control agents (fungi, bacteria and nematodes) have been produced.

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Pigs Root for Control

A centuries-old tradition is being adapted in trials to assess the ability of pigs to control an invasive weed, *Gaultheria shallon*, in the New Forest in southern England. Created by William the Conqueror in the 11th Century, the New Forest was one of a number of extensive areas of England that he placed under his stringent Forest Law, which protected the sovereign's hunting rights, and prohibited land enclosure and cultivation. In so-doing, he serendipitously created the earliest conservation areas. The local inhabitants (or 'commoners') eventually acquired restricted grazing privileges, and these continue to this day. The word 'Forest' did not necessarily denote a wooded area. Even in William's day about half of the Forest was heath. Today, it remains a nationally important environment of woodland pasture, heaths and bogs. It contains remnants of old coppices and timber plantations, and its oak–beech woodlands include an exceptional number of ancient trees.

Gaultheria shallon, known locally as American Strawberry, was introduced to the New Forest from northwestern America about a hundred years ago. In its native country it provides food for deer and its edible black berries are part of the native Americans' diet. It is believed to have been introduced to this part of England as a garden shrub, although it may also have been planted as cover for pheasants. In open parts of the Forest, the plant's growth has been inhibited by grazing deer and ponies, but in enclosed areas it can grow up to 1.5 m high. It generally occurs in isolated patches, which indicates it spreads readily by rhizome growth and only rarely colonizes new areas by seed. However in one area is has spread to cover approximately 50 acres [some 20 ha]. In the New Forest, it is being tackled while it is still manageable. However its encroachment has already become a major problem on Surrey and Hampshire heathland.

Gaultheria shallon spreads by means of an intensive network of shallow underground roots or rhizomes. Techniques to control it usually involve spraying with Roundup or Timbrel, herbicides that have been approved for use in the Forest. However, where it has spread over a large area, alternative techniques are being considered to minimize the concentrated use of herbicide and to protect important wetland habitats adjacent to the affected region.

Pigs are readily available in the Forest as many of the local commoners, or forest farmers, own these animals. Traditionally they are released in the area during the autumn to eat fallen acorns, which are poisonous to other animals. These pigs may roam freely on the open Forest, but have rings through their noses to prevent them from rooting. Rooting, or turning-over soil with their snouts, is part of pigs' natural behaviour to find food.

The University of British Columbia has confirmed that *Gaultheria shallon* is not poisonous and is palatable to stock. Trials involved fencing two areas which both contained *Gaultheria shallon*, bracken (*Pteridium aquilinum*) and *Rhododendron ponticum*. Initially, trials involved the release of eleven young pigs in an area of 18 m × 18 m for a period of six weeks. A second phase of trials is currently being undertaken on a slightly larger adjacent plot, with three adult female pigs (or sows). The aim is to establish whether sows are more effective at removing the weed and less selective in their diet. During the trials, the pigs were provided with water and additional food to supplement their diet.

Results from the initial trial indicated that *Gaultheria* growth was effectively halted as the pigs had brought up the plants roots, although they had not significantly consumed any of the plants roots or foliage. The pigs did have a considerable impact on the bracken, readily eating both rhizomes and foliage. Damage to *Gaultheria* was generally incidental to the pigs' main goal of eating the bracken roots. A *Rhododendron* bush in the enclosure was ignored by the pigs, although its roots were disturbed by their rooting for bracken. Until next year, it will not be possible to determine the overall success of the trials by assessing the extent of *Gaultheria* regrowth.

These trials are part of work to remove invasive exotic species from the New Forest Special Area of Conservation (SAC). Funding to enable this work has been provided by the *Life* project, in which half of the UK£5 million project costs are provided by the European Union and the remainder by the project partners.

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Training News

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

Putting a ZIP into Training

The problems created by heavy reliance on chemicals for pest control in cotton led to the crop being an early target for IPM. However, uptake in many cases has been poor, and reliance on pesticides has continued, associated with health problems for farmers and pest resurgence. There are a number of documented cases of the success of farmer participatory methods in persuading farmers to use IPM approaches (e.g. in Pakistan: see *BNI* **19(2)**, 41N-42N), and often these involve training 'trainers' (extension officers and non-governmental organization field staff) who then share their acquired agroecological knowledge with farmers through Farmer Field Schools (FFSs). Now, a local non-governmental organization in Zimbabwe is developing a training scheme, which concentrates on giving training directly to farmers, and on encouraging them to facilitate learning amongst other farmers.

The Zimbabwe Institute of Permaculture's ZIP Research provides training and research in natural pest management for the communal farming sector in Zimbabwe. In the Zambesi valley they are assisting farmers who want to grow cotton organically. This is a resettlement area where low rainfall and extremely high temperatures are major constraints to production. With the current economic crisis in the country, smallholders are finding it increasingly difficult to afford agrochemical inputs and are looking for alternative farming practices that will reduce their input costs. ZIP Research's training is based on the FFS approach, with modifications to meet local circumstances and needs. Most significantly, for their organic cotton project, they are concentrating on training farmers to teach other farmers. Trainees as Farmer Field Workers (FFWs) for the project are selected by their community with guidance from ZIP Research, and undergo a four-week training course in natural pest management (NPM) and organic farming at ZIP Research's Eco-lab at Mt Hampden near Harare. The FFWs each undertake to pass on skills and knowledge, learnt through a series of experiments and discussions, to ten fellow-farmers on their return. FFWs are selected by their communities because of their leadership skills. Over forty FFWs have graduated since 1997, and the project therefore reaches some 400 farmers in the Zambezi Valley.

This is a 'development through trade' project which, according to Sam Page, directly challenges the 'donor dependency' that has been created amongst the rural population by donor-led development which has been imposed in the area.

Training in natural pest management within organic agriculture reduces production costs because it eliminates the use of pesticides. It also enables farmers to receive an organic premium when they sell their produce to Cargill. Part of this premium will be used to provide remuneration to FFWs who perform well. The training provided by ZIP Research covers the requirements for the crops to be certified as organic, as the FFWs are also responsible for the internal control system. The organic cotton the farmers produce is now certified by the Dutch company Ecocert and bought at around a 20% premium by Cargill for separate ginning. The Harare office of AgroEco is responsible for the marketing of the organic lint. The organic lint from last season is currently being made into T-shirts, which will be sold in the UK through the 'Friends of the Earth' catalogue.

The training course focuses on practical skills and experimentation by the trainees in the laboratory and field, the toxicology of pesticides, understanding natural enemies, plant diseases and how they spread, pest and predator survey techniques, germination and plant growth processes, and soil organic matter determination; as well as concepts and discussion on topics such as socioeconomic aspects of organic cotton production and marketing including a visit to the local ginnery. As an example of the field studies carried out, the organic farmers have observed an effective black ant predator that can be encouraged into cotton by intercropping with cowpea. The ant benefits from the shade and feeds on the nectaries in the cowpea, and will pull out bollworms from the bolls of the cotton plant. Farmers use intercropping with sorghum and okra to trap bollworms, and plant live fences and intercrop with yellow flowering plants, such as sunnhemp and mustard, to attract natural enemies. The use of herbal remedies such as *Tephrosia vogelii* are recommended only as a last resort.

During their training, FFWs develop their own tailor-made curriculum to run back in their community including socioeconomic aspects such as local surveys of the economics of pesticide use amongst farmers who have not yet converted to organic agriculture, and agroecological studies on natural enemies and intercropping. They are also assisted by ZIP Research to conduct small-scale experiments with their farmer colleagues. Among the topics for current research farmer field workers have prioritized for testing are the effects of intercropping on pests and natural enemies, together with the search for viruses to control bollworms. Currently, the organic marketing regulations permit the use of chemically treated seed for the first two or three years only and farmers must show that they are exploring non-chemical alternatives. One possible alternative is seed treatment with ash. ZIP Research and the farmers are also studying cotton yield differences between organic and conventional cotton. *Alternaria* infection in different cotton cultivars will be investigated once these can be obtained: access to cotton seed in Zimbabwe is controlled by chemical companies. Another aim is to assess local market opportunities for organic groundnuts, which would bring more women into the project.

ZIP Research aims to expand its training programme in 1999, using private sector funding facilitated by DANIDA (Danish Development Agency) to support another development through trade project. Once a market is secured, they will run training courses in organic vegetable production. These will cover NPM techniques for a range of pests that have been identified, including rootknot nematodes and red spider mite, and address the problem of an acute shortage of on-farm biomass to improve soil fertility. It is intended that these farmers will supply a local food processor with organic fruit and vegetables that can be exported to Denmark at a premium.

Sources: Pesticides Trust (1998) Success with cotton IPM. A briefing for the IPM in Developing Countries Project funded by the European Commission Environment in Developing Countries budget (DGVIII). London, UK; The Pesticides Trust. *Pest Management Notes* No. 10, p. 3.
Sam Page & Shepherd Musiyandaka, pers. comm., 1998.

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Internet Round-up

By: Tony Little, Technical Support Group to the Global IPM Facility, CABI Bioscience.

This quarter, Round-up focuses on the conservation of natural enemies.

I have always been slightly wary of conducting 'broad spectrum' literature searches on the net, ever since a search on IPM in spice crops threw up 'Mama Paprika's Red Hot Web Page' (I forget the address now). Further investigation secured me an almost instantaneous interview with the IT manager and a lecture on appropriate use of company technology!

So it was with some trepidation that I tapped 'conservation' into the search engine, asking it to search within the results of two previous requests 'biological control' and 'natural enemies'. This yielded a few useful looking sites, but the majority were at some variance to the subject.

http://www.ucpress.edu/books/pages/8180.html, the University of California Press site, was among the more relevant pages. It carries useful reviews of recent publications, one of which, 'Enhancing Biological Control' edited by Charles Pickett and Robert Bugg, focuses on the role of conservation of natural enemies in biological control.

Staying with the University of California, UC Davis post their forthcoming activities, including a course on conservation and augmentation in biological control, at **http://ucdnema.ucdavis.edu/imagemap/nemmap/ENT135/12aCons.htm**

http://www.rain.org/~sals/cotton.html, linked to the RAIN (Regional Alliance for Information Networking) site, was the only other page of real interest and carries an informative article about biological control in cotton, within which there is a good discussion on conservation in cotton systems.

It seems, then, that the bulk of information on conservation of natural enemies is to found at sites with a somewhat broader subject matter, and here I turn to my 'Blue Chip' sites.

http://ipmwww.ncsu.edu/biocontrol/2a.htm/#2, a site within the Biological Control Virtual Information Center includes a chart listing commercially available natural enemies and pesticides that are compatible with them. While this is aimed at augmentative releases, it contains pesticide effect data for some important generalized predator groups such as lacewings and ladybirds which may be applicable to field use.

http://www.igc.org/panna/pestis.html carries the Pesticide Information Service (PESTIS). PESTIS is an on-line database that contains pesticide reform-related material, including articles, newsletters, reports and action alerts. While I could find no articles relating directly to conservation of natural enemies using the site search engine, there were a number of articles, such as 'Benefiting from Bugs' by Dan Imhoff, that contained a discussion on the topic.

http://www.wisc.edu/entomology/mbcn/fea201.html, which is home to the on-line journal 'Mid-west Biological Control News' proved to be the most useful site. Of particular interest was an article entitled 'Conservation of Natural Enemies: Keeping Your Livestock Happy', but which, rest assured, is entirely entomological, and is a nice introduction to conservation as a biocontrol strategy, with a useful list of references and contacts.

So a piecemeal and somehow rather unsatisfying search this quarter, but what it does do is highlight the lack of easy to locate, informative sites on this crucial, but evidently neglected aspect of biological control systems.

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Announcements

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

Scientists Link up on Evaluation of Transgenic Organisms for IPM

Readers of *BNI* will be well informed about recent developments in biotechnology for crop production, and the concern that these technologies are not being developed or deployed as components of sustainable IPM with a mind to their interaction with other aspects of pest management. In October 1998, experts in field evaluation of *Bt* crops and related biotechnologies from China, Australia, Europe and North and South America met to develop a new IOBC (International Organization for Biological Control) Global Working Group on "Transgenic Organisms in Integrated Pest Management and Biological Control" which is intended to address these issues. This new Working Group will provide a forum for disseminating information on published and ongoing research, for discussion and for development of collaborative projects. Its terms of reference identify five specific areas of co-operation: (1) developing methods for measuring non-target effects and other aspects of efficacy and environmental impact, (2) developing methods and protocols for resistance management, (3) improving monitoring systems for early detection of resistance and other environmental changes arising from release of transgenic organisms and (4) engaging farmers and extensionists in the process of determining whether and how to use transgenic organisms in local IPM systems. The Working Group will focus on the development of sound scientific approaches to the evaluation and implementation of transgenic organisms in IPM, and will provide its findings through reports and on a website. It is designed specifically to engage scientists in public sector institutions from both the developing and developing world, because it is here that capacity to evaluate transgenic organisms in pest management has lagged well behind the deployment of these technologies in the field.

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A Symposium on the Ecological Effects of Biological Control

In October 1999, an international IOBC (International Organization for Biological Control) Symposium will be held on Evaluation of Indirect Ecological Effects in Biological Control in Montpellier, France. The Symposium promises to bring leading population and community ecologists together with biological control experts to consider the basic ecological processes which determine the impact of biological control in ecosystems, and how this might lead to improved methods for prediction and evaluation. Recent meetings about safety in biological control have highlighted non-target issues in a way that has tended to polarize discussion around the rights or wrongs of past biological control programmes. By setting aside the issue of how risks are weighed and judged, and focusing on the ecological measurement of target and non-target effects, this Symposium intends to move this subject forward in a positive manner towards improved methodologies for biological control. The first day of the three-day meeting will be devoted to keynote presentations on ecology and ecological approaches to biological control, followed by a day of submitted papers and posters, and finally a workshop to identify next steps. The Symposium is being organized at AGROPOLIS International in Montpellier by the IOBC Permanent Secretariat and the Complexe Internationale de Lutte Biologique Agropolis.

See: http://www.agropolis.fr/iobc

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CABI Bioscience Course

A course on biological pest management is to run from 31 August to 24 September 1999 at CABI Bioscience UK Centre. The course is aimed at agricultural researchers and extension workers, including crop protection staff who wish to broaden their knowledge of pest management. Participants will learn the principles and basic methodology of biological pest management, how to conserve predators and parasites, how to introduce natural enemies from the native habitat of exotic pests, and how to culture arthropod and microbial control agents for field release. Participants may also select modules from an Entomology Foundation Course (16 August – 24 September). The course fee of UK£3600 includes tuition, all materials and self-catering accommodation.

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Michigan IPM Course

An IPM course, running from 25 July to 6 August 1999 at Michigan State University, will use the 'train the trainers' approach to team building, knowledge sharing and participatory learning for scientists from developing countries. The short course will provide 'hands-on' experience in integrated management of insects, diseases and weeds in field, vegetable and fruit crop ecosystems. The course aims to provide a mixture of traditional and experimental learning situations addressing the design, implementation and evaluation of IPM programmes. The course costs US$3285, including registration, fees, food and lodging and health insurance. The deadline for applications is 30 June 1999.

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Conference Reports

Water Hyacinth Working Group

The first global working group meeting for the biological and integrated control of water hyacinth under the auspices of the International Organisation for Biological Control (IOBC) was held at St Lucia Park, Harare, Zimbabwe on 16-19 November 1998. This meeting was attended by 47 delegates from 20 countries, including Argentina, USA, United Kingdom, Australia, Papua New Guinea, China and India. The majority of the delegates were from Africa, and South Africa, Angola, Zimbabwe, Zambia, Malawi, Uganda, Kenya, Tanzania, Côte d'Ivoire, Benin, Nigeria, Burkina Faso and Egypt were represented.

The workshop was divided into five sessions during which 20-minute oral papers were presented. Topics covered included the implementation and post-release evaluation of natural enemies, research into new natural enemies for water hyacinth and the need for an integrated approach to the control of the weed. The water hyacinth problem on Lake Victoria was the focus of much discussion and it was encouraging to note that not only is the biological control of water hyacinth well underway in this region, but also that it is achieving good results. There were a number of reports from countries where biological and integrated control of water hyacinth is being implemented and also from Burkina Faso and Angola where biological control programmes have recently been initiated. During the workshop there was a field trip to Lake Chivero just outside Harare where an integrated control programme with the emphasis on biological control has been successful.

It was evident from the meeting that there is a need for a globally coordinated effort on water hyacinth, which would prevent the costly replication of research. To this end, a water hyacinth clearinghouse was proposed to facilitate access to scientific, socio-economic and technical information globally.

The proceedings of this meeting are to be published shortly. The second global working group for the biological and integrated control of water hyacinth is to be held in China in 2000.

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Invertebrate Pathology

The VIIth International Colloquium on Invertebrate Pathology and Microbial Control and the IVth International Conference on *Bacillus thuringiensis* held in Sapporo, Japan on 23-28 August 1998 were attended by some 400 delegates. The conference was divided into topic sections: *Bacillus thuringiensis* (*Bt*), viruses, nematodes, fungi, microbial control, bacteria, microsporidia, marine invertebrates, entomophorales, insect immune system and insect cell culture.

The conference started with the Founder's Memorial Lecture: 'Karl Maramorosch: great leader of invertebrate tissue culture and pathology'. The honouree, Professor Maramorosch (State University of New Jersey, USA), who is now in his eighties, attended the conference and is still very active in the field of virology. The Memorial Lecture considered Professor Maramorosch's extraordinary life and his role as an exceptional scientist in the field of virology.

A symposium was held on 'Biology and Utilization of an Entomogenous Fungal Genus *Cordyceps*' which included a presentation by Professor Mitsuaki Shimazu from the Forestry and Forest Products Research Institute, Japan on the use of *Cordyceps militaris* to control beech caterpillar, *Quadricalcarifera punctatella*. Another interesting paper was presented by Professor Sung of the Republic of Korea in which he described *Cordyceps* found in Korea, and talked about mass production of artificial fruiting bodies in potato dextrose broth with silkworm pupae on unpolished rice.

A microbial control symposium entitled 'Microbial Insecticides: Novelty or Necessity?' was well attended. This session concentrated on the successes and failures of microbial insecticides in different uses. Dr. H. Evans, from Forest Research, UK, highlighted the need to understand the life cycle of the organism before relevant control could be successful. Dr. T Jackson, from AgResearch, New Zealand, had looked at controlling soil pests and related problems which has led to recommendations that co-evolved organisms are probably the most suitable for controlling such pests. Dr. Jackson also emphasized the importance of looking at economic production, delivery systems and securing a suitable market niche, which can be very variable.

Overall, the conference was very interesting and stimulating and proved of value to students and scientists alike.

By: Belinda Luke, CABI Bioscience UK Centre (Ascot)

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OECD Safety Workshop

An OECD (Organisation for Economic Cooperation & Development) workshop on 'Sustainable Pest management: Safe Utilization of New Organisms in Biological Control' was held in Montreal, Canada on 27-30 September 1998. The workshop was jointly organized by Dr H. Hokkanen (OECD Directorate for Agriculture, France) and Dr R. Trottier (IPM Associates, Canada) under the auspices of Agriculture and Agri-Foods Canada. Thirty international scientists, covering a range of disciplines, were invited to a 'weekend retreat' outside Montreal to present their thoughts on the issues and needs for research in OECD countries in order to ensure sustainability of agricultural systems through the safe use of organisms in biological control. The brief was to prepare and present these thoughts in the form of a short (ca. 1500 word) discussion paper, all of which were compiled and numerically arranged in dossier form under the programme headings: Policy and regulations for registration of microbial organisms (W. Sexsmith, B. Jensen, G. B. Prideaux, G Barden and P. Hutton); Research challenges and needs for safe use of microbial organisms (S. Dupont, B. Blum, R. J. Cibulski, J.-C. Côte & M. Goettel, J. Boisvert, T. A. Jackson, S. Keller, K. A. Jones, H. Evans and L. Solter); Research challenges and needs for safe use of arthropods (B. Philogene, K. Hopper and R.-U. Ehlers); and Research challenges and needs for safe use of transgenic organisms (E. Balazs, M. Tepfer, M. Masamichi, L. Sagi, M. Giband, J. A. Baum, I. Gard, L. Hornok, M. Hoy and M. Klein). The papers were followed by a discussion session in order to identify the issues, to draw up resolutions and to make recommendations. These were collated by facilitators, who further modified them, with additional inputs from selected scientists, and at a later date presented them in a draft document.

The following is a brief résumé of the issues identified with the appropriate recommendations.

1 Sustainable pest management: governments should exercise leadership in developing policies and programmes that support biological control as a key component of sustainable pest management.

2 Harmonization: with limited resources, small profit margins and restricted markets for biological control products, every effort should be made to facilitate their registration through global harmonization of appropriate regulatory requirements.

3 Cooperation and information exchange: member countries should promote and facilitate cooperation between all the parties concerned, both nationally and internationally, to meet societal needs for sustainable pest management. This should include the establishment of databases on taxonomy, biosafety, safety management and monitoring.

4 Education, communication and public confidence: governments should facilitate the participation of all stakeholders in ensuring that biological control is properly understood, promoted and implemented

5 Funding for biological control: governments should ensure that adequate funding is available to establish and maintain core competence, as well as the databases and links necessary for research and implementation of biological control, and that sustainability is a key criterion for application of public-good funding for pest management.

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Proceedings

Biocontrol of Sirex

Sirex noctilio, an important pest of pines, was first reported from South America in 1980, and is now a major threat to pine production in the southern cone. At the first meeting of the Permanent Working Group on Silvo-Agricultural Health in 1992, the southern cone countries identified *Sirex noctilio* as the pest that posed the greatest threat to conifer plantations in South America. A regional conference on the wasp, also held in 1992, recommended the creation of a management programme based on biological control. In the years since, Brazil, in collaboration with organizations in Australia, the US Forest Service and CABI Bioscience (formerly IIBC), has developed a programme, in the course of which it has introduced of a nematode and parasitic wasps from Australasia.

These proceedings* contain papers presented at an international workshop held at EMBRAPA (Empresa Brasileira de Pesquisa Agropecuaria) in Colombo, Brazil on 4-9 November 1996. The workshop provided technical underpinning of the programme by creating a forum to discuss rearing and release methods for the biological control agents. To facilitate dissemination of the information further, all the papers are presented in these proceedings both in English and in Spanish or Portuguese.

*Tadeu Iede, E.; Schaitza, E,; Penteado, S.; Reardon, R.C.; Murphy, S.T. (*eds*) (1998) Proceedings of a conference: training in the control of *Sirex noctilio* by the use of natural enemies. Morgantown, WV, USA; USDA/US Forest Service, Forest Health Technology Enterprise Team, Publication No. FHTET 98-13, 200 pp.

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