General News

Comb Jelly Jonahs

Comb jellies, or ctenophores, are a phylum of marine invertebrates that received little attention until an environmentally and economically disastrous invasive alien species, *Mnemiopsis leidyi*, raised their profile in countries bordering the Black Sea some 20 years ago. They are now a hot topic in the countries around the Caspian Sea, where the results of extensive collaborative studies have given scientists the confidence to call for the introduction of a biological control agent from the same phylum. The comb jelly *Beroe ovata* arrived serendipitously in the Black Sea and its control of *M. leidyi* there has played a vital part of restoring that ecosystem. Its introduction to the Caspian is now considered the best option for controlling *M. leidyi* there.

Mnemiopsis leidyi was pre-adapted to succeed as an invasive species. Native to temperate and subtropical bays and estuaries along Atlantic seaboards from 43°S in Argentina to 41°N in Massachusetts, USA, it tolerates an extremely wide range of environmental conditions (surviving temperatures of 1–32°C and salinities of 3–75 p.p.t.). It is a generalist feeder and responds to elevated food levels by increasing ingestion rates and hence growth. Its main food is zooplankton but it also feeds on fish eggs and larvae. It consumes on average 70% of its body weight per day, but ratios of up to 1500% have been recorded at high food concentrations, and individuals can double in size each day. Comb jelly populations shadow rises and falls in zooplankton populations, which are regulated by the availability of their phytoplankton food and thus peak in summer. Comb jellies are self-fertilizing hermaphrodites and members of the genus *Mnemiopsis,* in particular, have rapid reproductive rates; at optimal temperatures *M. leidyi* reaches maturity in less than 2 weeks and each adult produces some 8000 eggs per day. While these properties underlie *M. leidyi*'s success in its introduced range, human intervention is also implicated. International shipping and, more specifically, unregulated discharge of water from ships' ballast tanks facilitated its relocation from the New World to the Black Sea and much of its subsequent dispersal through the region.

The spread of invasive species (including vertebrates, invertebrates and microscopic organisms) is identified by the CBD (Convention on Biodiversity) as one of four main threats to marine ecosystems, and ballast water is one of the key pathways for their movement. Semi-closed and closed seas, as 'island' habitats, are particularly at risk of invasion by species such as *M. leidyi*, which are carried around the globe by the shipping industry, in ships' ballast tanks. According to the World Wildlife Fund (WWF), about 4000 different species can coexist in the ballast water of a ship at any given time. The size of the threat has increased in concert with the increase in international trade that has accompanied globalization. In February this year, following 10 years of negotiations, the International Maritime Organization (IMO) introduced the International Convention for the Control and Management of Ships' Ballast Water and Sediments, which will impose strict controls on the release of ballast water in an attempt to rein in the spread of invasive species. The convention will come into force 12 months after it has been ratified by 30 states (representing 35% of world merchant shipping tonnage), which may not happen for some years and until then the movement of invasives around the world in ballast water continues. The water systems of Europe and western Asia are particularly at risk of onward spread as the major water bodies are linked by canals and rivers through which invasive species may travel, unaided or with shipping. The Iranian Government (and thus taxpayers) paid compensation to fishermen for part of their *M. leidyi*-related losses, but a key issue is how livelihoods can be protected from the impact of future aquatic invasions. Clearly, legal aspects of responsibility and compensation for biological invasions need to be addressed.

Silver Bullet in the Black Sea

The Black Sea is the world's largest semi-enclosed brackish sea. It is joined to the Mediterranean by the Bosphorus – Sea of Marmara – Dardanelles water system, and to the smaller Sea of Azov to the north by the Kerch Strait. It receives abundant water from a number of rivers, notably the Danube in the northwest, and is less saline (18–22 p.p.t.) than the Mediterranean (<39 p.p.t.) to which it is a net exporter of water. In the latter half of the 20th century the Black Sea suffered from pollution, particularly in the northwest where agricultural intensification in bordering countries led to eutrophication, and over-fishing that wiped out populations of all the traditionally harvested species of large fish (and the fishing industries of the Black Sea nations had to switch to smaller species).

Mnemiopsis leidyi was first recorded in the Black Sea in November 1982, almost certainly introduced via ballast water discharged from ships from the western North Atlantic. In the first years after its arrival it was recorded from sites around the northwestern and later the northeastern Black Sea coast in summer and autumn, and by late 1988 it had spread throughout the water body. *Mnemiopsis leidyi* overwinters in the open sea. Surviving individuals grow to maturity during the spring and summer. Reproduction begins in areas of good food supply in June–July and continues into September–November although it is most intense in August–September. Thus biomass peaks are recorded in August–September, and peaks in abundance (number of individuals) in September–November when the population contains numerous immature stages.

In 1989, the first population outbreak (bloom) of *M. leidyi* was recorded: the peak mean biomass was the highest ever recorded in the open sea (estimated at ≥2 kg/m^2). In contrast, populations of other zooplankton species were reduced to a great extent (15- to 40-fold) and some species disappeared from the samples completely. Fish populations in the Black Sea were decimated. *Mnemiopsis leidyi* competed with small fish for zooplankton food and preyed on the eggs and juvenile stages of some fish, including the summer-spawning and economically important anchovy (*Engraulis encrasicolus ponticus*) and horse mackerel (*Trachurus mediterraneus ponticus*). As populations of *M. leidyi* boomed, catastrophic declines occurred, once again, in the fishing industries of the Black Sea nations. Horse mackerel disappeared completely from Russian commercial catches. Catches of anchovy in Turkey were reduced 80% in 1990 (to only 70,000 tonnes). In contrast, one estimate suggested there was 800 million tonnes of *M. leidyi* in the Black Sea in summer 1989. For the years 1991–1992, annual direct economic losses from decreased anchovy catches alone were assessed as some US$330 million. Winter-spawning fish were not immune, with sprat (*Sprattus sprattus phalericus*) catches also plummeting.

However, in the following two summers, the peak biomass of *M. leidyi* in the Black Sea was much lower (one estimate put the mean peak in 1991 at about 130 g/m^2). In the following years the biomass of the invading comb jelly increased and in summer 1995 another peak biomass was some 3.5-fold higher than in 1991. Summer abundance of *M. leidyi* and other gelatinous zooplankton in the southern Black Sea was monitored between 1996 and 1999 by Ahmet Kideys (Institute of Marine Sciences, Erdemli, Turkey) and Zina Romanova (Institute of Biology of the Southern Seas, Sevastopol, Ukraine). They found the peak biomass was fluctuating, with the high peak biomass in 1995 followed by a lower peak in summer 1996 and then an upward trend in 1997 and 1998. Looking at the results as a whole, it can be concluded that populations of the invading comb jelly attained a phenomenal biomass after its arrival in Black Sea; within a few years, this had decreased as the invader's populations reached more stable numbers in the Black Sea environment, but from 1991 the population trend was upwards.

Research by Ahmet Kideys and colleagues suggested that the declines in fish and zooplankton populations in the early to mid 1990s were the result of food limitation; low glycogen content of individuals sampled in summer 1996 indicated starvation. These findings were corroborated by Tamara Shiganova (P. P. Shirshov Institute of Oceanology, Moscow) and coworkers from Russia, Greece and Belgium, working in the northern Black Sea between 1992 and 2000. They showed that biomasses of zooplankton and *M. leidyi* were negatively correlated, but also implicated temperature in the yearly fluctuations in *M. leidyi* populations. They found that winter temperatures affect spring population sizes, which in turn affect summer populations: the peak in 1995 followed a warm winter in 1994/95. Zooplankton populations staged a recovery from 1996 and species diversity increased – some species that had disappeared from samples in the early 1990s made a comeback. Numbers of immature anchovy also began to rise but total density remained low, especially in the northern Black Sea.

The extensive research on *M. leidyi* in its native range has shown that temperature, salinity, food availability and predation combine to determine its seasonal abundance. The ecology and phenology of *M. leidyi* in the Black Sea correlates well with those of its temperate brackish habitats in North America: it had acclimatized and occupied the same niche as in its native range – but individuals were bigger, densities higher and populations more abundant.

In 1999, however, the population of *M leidyi* plummeted throughout the Black Sea and the lowest average peak biomass (estimated at 12 g/m^2) was recorded since the population explosion 10 years before. Widely credited with this reversal in *M. leidyi*'s fortunes was another introduced New World comb jelly, *Beroe ovata*, which was known to be present in the Mediterranean. Ironically, the deliberate introduction of this second species as a biocontrol agent was being considered (following a meeting of experts from the international commission of the Joint Group of Experts on the Scientific Aspects of Marine Pollution [GESAMP] that proposed the introduction of potential predators for *M. leidyi* into the Black Sea) but there were concerns about possible impacts on native Black Sea comb jellies. *Beroe ovata* was first found in the Black Sea, in Bulgaria's inshore waters, in October 1997, and by 1999 it had spread throughout the Black Sea. *Beroe ovata* could feasibly have migrated from the Mediterranean via the Sea of Marmara, but morphological studies by L. N. Seravin (St Petersburg University, Russia) and Tamara Shiganova suggested it was introduced from the coasts of the USA, where *M. leidyi* also came from; this view was later corroborated in genetic studies by Keith Bayha (Delaware University, USA). A first bloom of *B. ovata* was observed in autumn 1999, accompanied by an immediate drop in *M. leidyi* numbers – a phenomenon observed all round the Black Sea by Bulgarian, Romanian, Ukrainian, Russian and Turkish scientists. Although mechanisms underlying previous fluctuations in *M. leidyi* populations had taken some unravelling, the contribution of *B. ovata* to the precipitous collapse of *M. leidyi* populations in 1999 was literally clear because it is easy to see what the transparent comb jelly is eating. A number of different research studies concluded that *B. ovata* was feeding exclusively on other comb jelly species and, because of its relative abundance, predominantly on *M. leidyi*.

Was *B. ovata* a rare biocontrol silver bullet and was the *M. leidyi* problem consigned to history? The following spring the outlook seemed promising: overwintered *M. leidyi* were found only in the warmest locations and at the lowest spring levels since its first bloom in 1989. However, *M. leidyi* summer populations were elevated in 2000, and again in 2001 (reaching levels similar to those recorded in 1989), with huge numbers of small specimens indicating very active reproduction. Was this a sign of failure? Not according to Tamara Shiganova and co-workers. It reflected adjustments in prey populations to an environment where a predator was now present. Their surveys demonstrated that there had been a recovery in fish egg densities (especially for the summer spawning anchovy and horse mackerel) together with a summer zooplankton bloom in those years. The increase in food supply, coupled with high sea temperatures in 1999–2001, allowed *M. leidyi* to bloom. But unlike in 1989 and 1995, in 2000 and 2001 the *M. leidyi* populations collapsed each September, within 2–4 weeks of the appearance of *B. ovata* and the beginning of its population build-up. With the population dynamics of *B. ovata* so closely tied to those of *M. leidyi*, while outbreaks of *M. leidyi* can be expected to recur, *B. ovata* can equally be expected to curtail them quickly.

A key question is what are the impacts of the controlling effects of *B. ovata* on the ecosystem of Black Sea? The slow recovery in zooplankton and immature fish abundance, biomass and species diversity that had been observed with falling *M. leidyi* populations during the 1990s were considerably enhanced following the arrival of *B. ovata*, and by 2000–01 they were comparable to pre-*M. leidyi* days. They fell and then rose again with the rise and fall of *M. leidyi* populations in the summers of these years. The recovery of the ecosystem is reflected in fish catches – notably sprat and anchovy – but most significant is the increased total fish catch, which reflects an increase in fish species diversity. In 2000, Russian scientists found anchovy in trawls for the first time for 5 years, together with some other species absent from summer catches since 1990. Also, in the southern Black Sea Turkish catches have attained record levels.

Thus *B. ovata* has brought about a spectacular recolonization of commercially important small pelagic fish species in the Black Sea. *Mnemiopsis leidyi* now occurs in great numbers only during the months of July and August and the summer population rise is attenuated. As a consequence, populations of other zooplankton have resurged and fisheries have staged a remarkable recovery.

From the Black Sea, *M. leidyi* spread to other seas of the Mediterranean basin: the Sea of Azov to the north, and south to the Sea of Marmara and (thence and/or by separate introduction) the Aegean and the eastern Mediterranean. However, the Black Sea seems to provide the perennially optimal conditions for it to thrive and, as the main habitat of *M. leidyi* in its adventive range, has been a source of *M. leidyi;* its abundance there may alter numbers of *M. leidyi* elsewhere since it is considered a potential exporter of this invasive species.

Caspian Confronts Crisis

The Caspian Sea, the world's largest inland water body, was relatively less accessible. Not a natural part of the Mediterranean system, it is connected to the Black Sea by the Volga–Don river and canal system. Warnings that *M. leidyi* could reach the Caspian Sea had been sounded as early as 1995. However, there was no mechanism to prevent the further spread of the pest, and *M. leidyi* was sighted for the first time in the Southern Caspian in November 1999 by scientists from the Iranian Fisheries Research Organization (IFRO) and Tarbiat Modarres University and in the Middle Caspian at about the same time by scientists from the Caspian Institute for Fisheries, Russia. A drop in fish catches in 1999 together with anecdotal evidence from Iranian fishermen who had observed a jelly-like plankton while fishing at night under lights were effective proof of the presence of *M. leidyi* in the Caspian environment. It seems likely that once again ballast water was the pathway – discharged into the Middle or Southern Caspian by ships that had reached the Caspian Sea via the Volga–Don Canal from the Black Sea or the Sea of Azov.

The Caspian spans different climatic zones; average winter surface temperatures range from 0–0.5°C at its northern ice-bound edge to 10–11°C in the south (summer temperatures are less variable, 24–28°C). The water body is divided into three parts: the Northern Caspian is a shallow lake (average depth 5–6 m) with salinity varying between 0.01 p.p.t. near the northern river mouths (including the Volga) to 10–11 p.p.t. at its boundary with the Middle Caspian; the Middle Caspian is a rift basin (average depth 190 m) separated from the deeper Southern Caspian (<1000 m deep) by an underwater ridge, and the salinity in these parts of the water body is 12–13 p.p.t. The arrival of *M. leidyi* in this unique, ancient water body was the latest environmental and economic disaster for the region; environmental conditions in the Caspian have been significantly degraded over the last 30 years, particularly by pollution and water level changes. The Caspian was the only water body that had preserved large stocks of the ancient group of sturgeon fish. Commercial sturgeon fishing accounted for about 90% of total world catch, until environmental changes (particularly regulation of rivers which destroyed spawning grounds and disrupted migration pathways, and illegal fishing after the collapse of the Soviet Union) caused sturgeon populations to decline greatly. Thus, although the region is rich in natural resources and developments (for example marine oil extraction) have brought prosperity, the Caspian ecosystem and the livelihoods of the riparian inhabitants are under threat from over-exploitation. The marine transport facilities that are important to the development of the region provide a pathway for invasive species, the most recent threat.

Differences in salinity are thought to underlie the establishment of *M. leidyi* in the Southern and Middle Caspian, rather than closer to the mouth of the Volga further north. Although the salinity of the Southern and Middle Caspian is lower than that of the Black Sea (18 p.p.t.) this has proved no obstacle to *M. leidyi*'s advance, far from it. A survey in July 2000 found that *M. leidyi* was widely distributed in the Southern and Middle Caspian, and by September it was found throughout the water body. Subsequent surveys showed that *M. leidyi* overwinters and spawns in spring in the Southern Caspian but spreads north during the summer. Reproduction has been recorded throughout the Southern and Middle Caspian. The spread of *M. leidyi* north from the Middle Caspian is dependent on wind-driven currents that also move more-saline water northwards. Survival of *M. leidyi* in the Northern Caspian is dependent on a combination of salinity (≥4.3 p.p.t.), temperature and perhaps other factors. Compared to *M. leidyi* in the Black Sea, the individuals in the Caspian were much smaller, but they made up for this by sheer numbers and it was in the Southern Caspian that biomass was highest. In both the Southern and Middle Caspian, summer biomass peaks were higher in 2001 than in 2000, and yet higher in 2002, reaching greater biomass and abundance in the Southern Caspian (Iranian waters) and Middle Caspian (Azerbaijan waters) than those recorded in the Black Sea at the height of the *M. leidyi* invasion.

Learning lessons from the impact of *M. leidyi* in the Black Sea, the response to the invasion in the Caspian Sea was rapid and coordinated. As a landlocked water body, it was feared that the impact of *M. leidyi* would be even more severe than in the Black Sea, and this fear was soon substantiated. Within 2 years of *M. leidyi*'s arrival, there were very significant decreases in other zooplankton throughout the Caspian; a community that had contained up to 25 species had been reduced to only three species and biomass was reduced close to 10-fold by 2001. Zooplankton abundance decreased gradually as *M. leidyi* populations increased, and was reduced to its lowest ever biomass in August 2001 in the southern Caspian when *M. leidyi* populations were at their peak. However, the peak in zooplankton biomass has switched from the summer to the winter, when minimum numbers of *M. leidyi* prey on them. The competition from burgeoning comb jelly populations decimated fish stocks that were already on the decline and there were sharp decreases in fish catches. In both Iran and Azerbaijan, catches of the anchovy-like kilka (*Clupeonella* spp.) fell by some 50% between 1999 and 2001. The falling fish stocks may also threaten the survival of large predators such as the endemic Caspian seal (*Phoca caspica*), whose favoured food is kilka and whose populations had already been decimated in recent years by canine distemper. Populations normally migrate south in summer in search of food, but this has been disrupted because animals are unable to build up the necessary fat reserves to sustain the journey. In addition, a decrease in the proportion of reproducing females has been recorded.

Following a decision of the Second Biodiversity Meeting of the Caspian Environment Programme (CEP) at Almaty, Kazakhstan in July 2000, CEP held the First International Workshop to discuss problems of the invasion of the Caspian Sea by *M. leidyi* at Baku, Azerbaijan in April 2001. At this time the situation was recognized to be serious. Biological control was identified as the best hope for a long-term solution, but the difficulties were not underrated and the introduction of another alien species to the Caspian ecosystem needed consideration. Participants recognized that *B. ovata* was unlikely to be a miracle solution in the Caspian; *B. ovata* is thermophilic and less tolerant of low salinity than *M. leidyi*. Another contender was the butterfish (*Peprilus tricanthus*), an American obligate gelatinous zooplankton feeder. However, the lack of knowledge about the fish compared with the abundance of information available on *B. ovata* from studies in the Black Sea (compounded by the recent success of *B. ovata* in the Black Sea and the chequered history of introduced vertebrate biocontrol agents) led *B. ovata* to be favoured. It was recognized that *B. ovata* is unlikely to arrive serendipitously, as it did in the Black Sea, and an informed decision on its introduction will need to be made, in line with the ICES (International Council for the Exploration of the Seas) Code of Practice on the Introduction and Transfer of Marine Organisms. To assemble the information necessary for this, a series of collaborative initiatives was undertaken by scientists in the region:

- Monitoring programmes for *M. leidyi* were initiated with training of Iranian and Azeri scientists; later a common monitoring methodology, developed by Ahmet Kideys and Tamara Shiganova, was adopted; see: www.caspianenvironment.org/mnemiopsis/mnemmenu5.htm
- A programme of research measured physiological parameters of *M. leidyi* in the Caspian, data that could then be used for population modelling.
- The feasibility and possible impact of *B. ovata* introduction on the target and other biota was evaluated, research that included evaluating physiological characteristics and ecological and rearing studies on *B. ovata* conducted at Mazandaran Caspian Ecology Research Centre, Iran on the southern Caspian coast.

The *Mnemiopsis leidyi* Advisory Group (later renamed the Invasive Species Advisory Group) was set up to coordinate research and assess progress and future plans. By the time its first workshop was held in December 2001, monitoring indicated that the invasion of the Caspian was progressing much faster than in the Black Sea and that the need for control had become urgent. Since then, working together, the scientists from the countries around the Caspian have provided much of the necessary information.

Physiological studies conducted in Mazandaran and more recently in Sinop, Turkey have shown that *B. ovata* can be acclimatized successfully to lower Caspian salinities (12.6 p.p.t.) from 18 or 22 p.p.t. in a matter of days. Measurements of feeding, respiration and growth rates were also made in the Caspian environment; daily ingestion rates of 45–765% wet body weight (highest values for smallest individuals) were recorded in the laboratory – values close to those recorded for the Black Sea, which encourages the view that *B. ovata* would be able to impact significantly on *M. leidyi* populations in the Caspian. In addition, *B. ovata* of all sizes ingested both small and large prey – a significant point given the small size of Caspian *M. leidyi*. While more research is still needed on interactions with other organisms and parasites *B. ovata* might contain, together with modelling studies, progress is promising – with one caveat.

Rearing has proved a challenge. In initial experiments carried out in Mazandaran using Black Sea and Caspian water, adults spawned and eggs hatched, but larvae did not feed and none survived more than 24 hours. Although immature stages do tend to be more sensitive to salinity than mature individuals, the fact that breeding failed in both Black Sea and Caspian water suggested that salinity was not the problem. The scientists conducting these, the first, experiments on rearing *B. ovata* noted that it is very sensitive to handling, and the immature stages particularly so. They suspected the mechanics of the rearing method to have been at fault. Research has also made clear that timing is critical: peak spawning in *B. ovata* seems to be limited to a 2-week period in late August/early September. Subsequent studies at Sinop in summer 2003 by Ahmet Kideys together with Galina Finenko (Institute of Biology of the Southern Seas, Sevastopol, Ukraine) and Levent Bat (Faculty of Fisheries, Samsun University, Turkey) yielded promising results, suggesting mass production of *B. ovat*a in Caspian water is achievable. However, at the moment larvae can still not be reared through to the adult stage, and more investigations are needed to be able to breed *B. ovata* in captivity.

An alternative strategy would be to introduce *B. ovata* directly from the Black Sea or Sea of Azov. There are a number of additional safety constraints posed by such an approach (notably to ensure that disease pathogens or other new species are not inadvertently introduced with *B. ovata*) but research suggests that such conditions could be met.

On 21–24 February 2004, the scientists met again for an international meeting, this time in Tehran. The First Regional Technical Meeting on Possible Introduction of *Beroe ovata* into the Caspian Sea*, held jointly by CEP and IFRO, reached agreement to go ahead with a proposal to introduce *B. ovata* to control the invading *M. leidyi* in the Caspian Sea. This proposal along with the Environmental Impact Assessment (EIA) – prepared in line with the ICES Code of Practice on the Introduction and Transfer of Marine Organisms – have been circulated to responsible bodies in the riparian countries in an effort to obtain joint approval for an introduction of *B. ovata.* If this is obtained, an introduction could be made as early as August–September this year. The EIA paints a stark picture of the likely outcome of non intervention against *M. leidyi* in the Caspian. It notes that, on balance, its impact on the Caspian ecosystem 2 years after its invasion is expected to be considerably greater than its impact after 6 years in the Black Sea. The EIA also draws attention to experimental evidence suggesting that *M. leidyi* predation pressure in the Caspian is likely to lead to a considerable and severe reduction in the zooplankton populations, which would threaten the entire ecosystem.

This time science is one step ahead of politics. Most of the time politicians ask questions and want instant solutions to problems, while scientists need time to research and prepare a response. The Invasive Species Advisory Group project has already made its mark, illustrating how the information required by the international Code of Practice can be provided by a focused and collaborative approach to research and how cooperation between scientists of countries facing a regional problem can lead to a consensus on its solution. It is now up to politicians to decide whether the biocontrol introduction should be made.

Further Information

Caspian Environment Programme:
www.caspianenvironment.org

Global Ballast Water Management Programme:
http://globallast.imo.org/index.asp

Iranian Fisheries Research Organization:
www.ifro.org
*Papers from this meeting are on the IFRO website

Group on Aquatic Alien Species (Russia), Regional Biological Invasions Center:
www.zin.ru/projects/invasions/gaas/

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Biocontrol of Hemlock Woolly Adelgid: a Race against Time

The hemlock woolly adelgid, *Adelges tsugae* (HWA), has become the most devastating insect pest of hemlock forests in the eastern USA. Native to Asia, HWA was first reported in Oregon in 1924 and in eastern North America near Richmond, Virginia in 1951. For decades it was considered a minor pest of ornamental hemlocks. It was not known to cause damage on western hemlocks (*Tsuga heterophylla* and *T. mertensianna*) and it was easily controlled in the ornamental landscape using a variety of insecticides. By the mid 1980s, it was found in hemlock forests in Virginia, New Jersey, Connecticut and eastern Pennsylvania. In the forest environment, adelgid populations rapidly increased and tree mortality soon became extensive. Hemlock mortality at the Shenandoah National Park in Virginia averaged 50% in 2000, with 99% of the remaining hemlocks in a severe state of decline. In New Jersey, hemlock mortality currently exceeds 90% in areas where HWA has been established the longest and less than 13% of the remaining stands are considered healthy. HWA is now established in 16 states from southeastern Maine to northeastern Georgia and westward into eastern Tennessee. Its recent establishment in the Great Smoky Mountain region threatens some of the oldest and largest specimens of eastern hemlock (*T. canadensis*) in North America. Also at risk is the rare Carolina hemlock (*T. caroliniana*), a species with limited distribution in the southern Appalachians.

There are no known parasites of Adelgidae and existing natural enemies are not effective in controlling HWA in eastern North America. Furthermore, there are no chemical control options suitable for management in the forest environment. As such, classical biocontrol has become the keystone in the race to save eastern hemlock forests. In the mid 1990s, the USDA (US Department of Agriculture) Forest Service and its state, federal and university cooperators initiated a coordinated effort to locate, evaluate and establish a complex of host specific natural enemies. To date, these efforts have led to the investigation and introduction of a number of biocontrol agents of diverse geographical origin.

- *Sasajiscymnus tsugae* [formerly *Pseudoscymnus tsugae*]. Building on the discovery of a tiny coccinellid predator in Japan by Mark McClure of the Connecticut Agricultural Experiment Station, *S. tsugae* became the first natural enemy to be established in this biological war on HWA. Rearing methodologies developed by Dan Palmer of the New Jersey Department of Agriculture has led to mass production of this important predator and additional facilities have been established with North Carolina Department of Agriculture, Clemson University, University of Tennessee and, in the private sector, EcoScientific Solutions LLC. By the end of 2003, more than a million *S. tsugae* beetles had been released in hundreds of infested hemlock stands throughout 15 states.

- *Laricobius nigrinus*. As a predator of HWA in western North America, this derodontid beetle has been found to be highly host specific and active in the fall and winter months. Both research and rearing of *L. nigrinus* is being conducted at the Virginia Polytechnic Institute and State University under the direction of Scott Salom. Establishment of this predator began in the fall of 2003 at locations in six states. Further releases are planned in 2004.

- *Scymnus sinuandodulus*. Mike Montgomery of the USDA Forest Service Northeastern Research Station discovered that numerous predators of HWA existed in China including several species of *Scymnus* beetles. The focus thus far has been on *S. sinuandodulus,* as it shows the most promise as a predator of HWA and its life history makes it more suitable for mass rearing. The first release of this coccinellid predator is planned for 2004 and the release programme is expected to be expanded in the coming years.

- Entomopathogens. Research efforts led by Bruce Parker at the University of Vermont hold hope that pathogens may play a role in regulating HWA populations. Several promising fungal isolates have been identified and tests are currently underway to develop effective formulation and delivery systems.

Laboratory and field tests show promising results with each of these natural enemies but it will probably be several years before any are established in sufficient numbers to have an impact on HWA at the forest stand level. Because of this lag, areas selected for release are primarily along the leading edge of the infested region, where hemlock trees are healthy and infestation levels are at low to moderate densities. High-value natural areas like the Great Smoky Mountains are receiving the highest priority.

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Broadleaved Weeds Face Fungal White-out

A Canadian project aimed at finding fungal biocontrol agents for Canada thistle (*Cirsium arvense*) has identified a fungus with potential as a bioherbicide against a wide spectrum of broadleaved weeds. Canada thistle, introduced from southeastern Europe and the eastern Mediterranean in the 17th century, occurs across Canada as far as 58–59° North and is a serious weed in field crops and pastureland. Wheat losses in Saskatchewan alone have been estimated at Can$3.6 million per year.

The research started in 1985 with Canada-wide surveys coordinated by Agriculture and Agri-Food Canada, Saskatoon for the collection of diseased Canada thistle plants. Over the next 10 years, fungi were isolated from the plants and their properties studied by Karen Bailey (the lead scientist for the project). In 1996, when promising fungi were put through a screening programme designed to identify those most suitable for use in biocontrol, *Phoma macrostoma* began to stand out as an exceptional candidate. While it had no impact as a foliar spray, it proved highly pathogenic if applied to the soil. It acts by blocking chlorophyll synthesis, which kills emerging seedlings and adversely affects (although does not immediately kill) established plants. Strains of the fungus, which had been isolated from chlorotic lesions on leaves of Canada thistle from five provinces across the country, prevented more than 80% of weeds from growing when it was applied to weed-free or newly planted lawns. Field trials conducted over 3 years in Canada and USA backed up the initial results. As the studies took in a wider spectrum of plant species, it became clear that many broadleaved but no monocotyledonous species were susceptible. Weed species best controlled were Canada thistle, dandelion (*Taraxacum officinale*), scentless chamomile (*Tripleurospermum perforatum* [= *Matricaria perforata*]), chickweed (*Stellaria media*) and white clover (*Trifolium repens*). Something that started out as a Canada thistle biocontrol initiative now looks as though it could turn into something bigger. Indeed, Canadian press coverage has highlighted the potential of *P. macrostoma* for dandelion control in both urban and rural areas.

An effective bioherbicide for broadleaved weeds would help to overcome one of the drawbacks of conservation tillage systems. Such systems reduce wind and water erosion but lead to an increase in infestations of weeds like dandelion. These are usually controlled by herbicides but in some species, including Canada thistle, herbicides delay growth but do not kill the weed. Environmental and health impacts of herbicide use are also an issue, and this is not restricted to agriculture. In amenity situations, herbicide use is increasingly heavily regulated: for example, there are access restrictions associated with herbicide use, and many have been banned altogether by a number of Canadian municipalities.

The biopesticide approach could also complement classical biological control, for which Canada thistle has long been a target. Despite a suite of introduced and native natural enemies, control of the weed remains inadequate. The hunt for more agents continues along with efforts to improve the efficacy of those already established. Overhanging the classical approach, however, is increasing concern about the safety (i.e. host specificity) of introduced biocontrol agents. One of the insects introduced for Canada thistle biocontrol was *Rhinocyllus conicus*, which further south in the USA has become a *cause célèbre* for (not unanticipated) nontarget effects on native thistles. While no such impacts have been recorded on Canadian thistles, future exotic natural enemy introductions are likely to face more stringent regulation. In these circumstances, a native control agent with limited persistency has safety advantages. In nature, *P. macrostoma* occurs at very low levels, but has a wide geographic distribution. Extensive research on *P. macrostoma* has found that it does not remain in the soil for much more than 4 months after inundative applications, and is rarely present the year after application. Consequently, there would be no impact on crops planted the following year, and broadleaved crops in the rotation would not be adversely affected by using a *P. macrostoma*-based broadleaved weed control strategy for monocotyledonous crops.

There are a number of hurdles to be crossed before *P. macrostoma* can become a marketable product. Toxicology studies need to be completed to ensure its safety. In addition, reliable methods are needed for mass production of the fungus, and appropriate formulation, storage and packaging for it must be developed. All this will take time and money, and many promising biopesticides fail to become commercial products because the potential market is too limited to justify the investment. However, a broad spectrum of activity coupled with a wide range of lucrative applications makes *P. macrostoma* a good candidate for development as a bioherbicide. A 3-year research agreement with Scotts Canada will allow the commercial potential of *P. macrostoma* to be explored. If all goes well, a product could reach the shelves in 4–6 years.

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Biocontrol Shipments to the USA

Safe and rapid importation of natural enemies into the USA is a critical issue facing scientists who wish to bring in exotic biological control agents. The same is true for commercial companies that import beneficial organisms from production facilities overseas. Although the permits remain the same, the US Animal and Plant Health Inspection Service (APHIS) recently modified the importation process for bringing in live natural enemies, due to concerns about homeland security. These changes affect more the importation of exotic natural enemies for classical biological control programmes, than the importation of mass-produced beneficial organisms for augmentative biological control.

For commercial companies that import beneficial organisms from overseas for distribution within the USA, APHIS requires that all shipments arrive by bonded carrier to a designated port of entry where they are inspected. If the port of entry is not located near the company's headquarters, then the company incurs the additional cost of having the shipments forwarded to an airport or other pick-up facility nearby.

The scenario for biological control scientists is more complicated, however. Currently, any scientist importing live, exotic natural enemies from overseas has two choices. Live organisms may be shipped by a bonded carrier to a port of entry, where the shipment is received by a customs broker, permits are validated by Plant Protection and Quarantine (PPQ) inspection, and it is forwarded to the appropriate quarantine facility. However, many carriers will not ship live organisms, plus there are many potential hazards that may endanger the survival of living organisms during travel or delay their delivery. On the other hand, a scientist with the proper permits may hand-carry exotic natural enemies to the airport of entry, but there the scientist must turn them over to an agent of the Department of Homeland Security – Customs Border Protection – Agricultural Inspection. A privately contracted customs broker receives the package from customs and delivers it to PPQ for inspection and validation of permits. Following this, the material is either taken by the customs broker personally to a designated quarantine facility, or is shipped by the customs broker to the quarantine facility; the consignment is not returned to the scientist at the airport of entry. APHIS has been petitioned to modify this process so that the customs broker may hand over the package directly to a specified quarantine officer at the port of entry, but this request has not been authorized. Of course, never during this importation process is the package allowed to be opened until it reaches a quarantine facility.

To read the letter from APHIS to PPQ Form 526 permit holders regarding these changes, see:
www.aphis.usda.gov/ppq/permits/plantpest/policyletter10-15-03.pdf

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Developing a UK Standard Methodology to Assess the Risks from Non-Native Species

A key recommendation of the UK Government's recent non-native species policy review [see *BNI* 24(2), 38N (June 2003), UK non-natives review] was to "develop comprehensive, accepted risk assessment procedures to assess the risks posed by non-native species and to identify and prioritise prevention action". To develop the UK's approach to risk assessment of non-native species in line with these recommendations, Defra (Department for Environment, Food and Rural Affairs) has commissioned a new project: Contract CR0293 'Standard methodology to assess the risks from non-native species considered problems to the environment'. The year-long project began in January and is a collaboration between six organizations: Central Science Laboratory (CSL), Centre for Ecology and Hydrology (CEH), Centre for Environment, Fisheries and Aquaculture Science (CEFAS), Imperial College London, University of Greenwich and CABI Bioscience.

The main aim of this project is to design and test a general risk assessment system for the UK that can be applied to all non-native species, introduction pathways and receptor habitats. The project draws on the experience of plant health risk assessment schemes, such as that prepared by the European and Mediterranean Plant Protection Organization (EPPO) standard PM 5/3(1), first approved in September 1997, and the Australian weed risk assessment model (see Pheloung *et al.* 1999), but covers a much wider range of invasive non-native taxa and habitats. During the project a number of sample risk assessments will be undertaken, allowing the performance of the risk assessment scheme to be evaluated.

Review of Non-native Species Policy:
www.defra.gov.uk/wildlife-countryside/resprog/findings/non-native/index.htm

EPPO Pest Risk Assessment Scheme:
www.eppo.org/QUARANTINE/PRA/prassess_scheme.html

Pheloung, P.C., Williams, P.A. & Halloy, S.R. (1999) A weed risk assessment model for use as a biosecurity tool evaluating plant introductions. *Journal of Environmental Management* 57, 239–251.

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Is Biocontrol Good for Conservation?

A series of papers in the 'Conservation Forum' section of the February 2004 issue of *Conservation Biology** debates the future of biocontrol as a conservation management tool. Although some papers have a US focus in places, the arguments have a wider resonance.

The introductory paper by Mark Hoddle argues that biocontrol is a valuable tool for managing invasive species in conservation areas, "where the risks of doing nothing are unacceptably high", and deserves wider consideration for managing non-traditional exotic targets. He provides a positive economic and environmental assessment of the discipline as a whole, arguing that the relatively small number of successes (10% of arthropod programmes and <30% weed of programmes) have been so successful that their economic benefits have more than covered the costs of the failures. While accepting that nontarget effects have been recorded in a small proportion of projects and that many past introductions have simply not been monitored, he says that where nontarget effects have occurred, biological control practice has strayed from the theory. He provides evidence for this by analysing common elements of 14 introductions with recorded nontarget effects. Emphasizing the importance of regulation in promoting safe biological control, he discusses current legislation in the USA and New Zealand and backs the universal adoption of the Code of Conduct for the Import and Release of Exotic Biological Control Agents. He identifies 12 current biological control programmes in support of conservation and argues that biological control is perhaps the best and often the only means by which ecosystems degraded by invasive alien species may be restored. He also identifies 10 non-traditional targets for which biocontrol is being developed; six of these are vertebrate pests and he discusses possible mechanisms of novel biocontrol agents for these. He concludes by suggesting that biological control projects should be designed and executed within a regulatory framework including peer review of the need for biological control and its feasibility and for determining the data necessary to evaluate host specificity and the potential magnitude of impact on both target and nontargets. He accepts that such projects will be more expensive and calls for a balance in ensuring safety and economic feasibility.

The next three papers examine Hoddle's arguments.

Svata Louda & Peter Stiling predictably take issue with Hoddle's positive evaluation of the safety and efficacy of past control programmes. They highlight important reasons for caution and continuing development of improved risk assessment. Their overarching guideline would be "first, do no harm". They review a series of examples, cases either not referred to by Hoddle or for which they present a different interpretation, where nontarget effects have been recorded, and conclude that they reveal both unexpected interactions and unpredicted intensities of interaction between introduced biological control agents and nontarget native species. They then provide a critique of Hoddle's arguments for biological control. They ask, what are the multiple ecological effects of the many 'failures' where released agents persist but do not effect control? They note that 'high' in the term 'high host specificity' has a range of meanings and consider the implications of this in terms of host range expansion. They point out that the safety net of regulation is far from universal and that voluntary codes are voluntary. Lastly, they say that biological control may not be as risk-free as is assumed, arguing that it is difficult, maybe impossible, to predict the size of the outcome of the array of new interactions caused by an introduced agent in a new environment. While agreeing that biocontrol can be beneficial, they call for a focus on what is both effective and ecologically safe.

Raymond Carruthers, a "supporter and advocate for biological control when practised scientifically and systematically", emphasizes that the purpose of his paper is to stimulate thought and build bridges not barriers, "because together we have many important hurdles to cross in the fight to contain invasive species." He has no doubt of the size of the problem posed by invasive alien species nor that the problem is increasing. He acknowledges that introducing exotic biological control agents into natural ecosystems is controversial. He discusses how far many of these ecosystems have been transformed over recent centuries and the importance of understanding how they function now. In reality, he notes, decisions about control have to be made without complete knowledge, which introduces risk, and he advocates an open, science-based decision-making process. He accepts that nontarget effects do occur and endorses efforts to minimize these. However, he argues that potential nontarget effects need to be considered in the context of the impacts of non-biocontrol introductions and against the result of doing nothing. He advocates the assembling of multi-disciplinary teams, and uses the example of the saltcedar biocontrol programme in the USA to illustrate how groups with diverse outlooks can, by working together, exchanging views on a regular basis and compromise, reach consensus on solutions.

Trexler Proffitt Jr.'s analysis shows how institutional change will be as necessary as effective science if biocontrol is to be more widely adopted. He points out that conservation issues cross traditional disciplinary boundaries and create conflicts that are only partially science-based. He contends that many debates superficially about science are actually about what is perceived as normal or safe. He compares "the dominant pest-control and cost–benefit logic" of US agroindustry (where biological control practice is rooted) with the "strong preservation, anti-intervention logic" of conservationists. He emphasizes how difficult it is to challenge entrenched beliefs: "People simply do not update their beliefs overnight in the face of evidence." He explains that evidence tends to be processed in favour of existing beliefs and interests. He notes that while "science is often a truly international field in general, policy is mostly provincial", and for the scientists used to the wider world, gives an interesting slant on how US policymakers might view evidence from France and New Zealand! He questions how acceptable simple or 'low-tech' solutions (in which category he places biological control) are to US agroindustry, and also explores the potential impact of an expanded biological control sector on the *status quo* of other institutions.

Hoddle responds to these commentaries in a final paper, most of which deals with answering the criticisms raised by Louda & Stiling. Nevertheless, Hoddle agrees with Louda & Stiling that the determination of safety is one of the biggest challenges facing biological control and highlights the problems associated with translating results between lab and field, and research into this. He considers Proffitt's comment about people's reluctance to alter basic beliefs, and says that a paradigm shift in accepting new ideas about safety will be slow. However, he describes how such a shift has happened in insect biological control over recent decades, with a switch in preference from generalist natural enemies to more specific agents to reduce nontarget impacts – a trend that is gathering momentum. He agrees that assessing the value of biological control, risk assessment and evaluation of agent safety can help justify biological control, and supports Carruthers' championing of multi-disciplinary teams to address issues related to biological control for invasive species in conservation.

**Conservation Biology* 18(1), pp. 38–64.

International Issues in the Use of GMOs for the Management of Mammal Populations

In 2001, Elena Angulo, then a PhD student in Spain, became concerned about the use of GMOs (genetically modified organisms) being developed in Spain for the management of wild rabbits (*Oryctolagus cuniculus*). A recombinant myxoma virus had been engineered to incorporate the gene that coded for the VP-60 protein of rabbit haemorrhagic disease (RHD) virus. The virus used was an attenuated myxoma virus that had been carefully chosen so that the recombinant virus would not kill the infected rabbit but instead would immunize any rabbit it infected against both diseases. This recombinant was also able to spread from rabbit to rabbit and so could be used to immunize wild rabbits. By catching and inoculating some rabbits, or by infecting rabbit fleas and achieving wider natural spread of the virus, it was considered possible to immunize a substantial part of a wild rabbit population and effectively inhibit disease spread. It was further shown that the recombinant virus had limited capacity to spread and that on each passage it infected fewer susceptible animals. This was considered advantageous in maintaining control over the recombinant virus. It would need to be re-introduced each year and therefore should not spread into areas where its use was unnecessary.

Angulo had misgivings about the safety of the work and the lack of knowledge on how to estimate the risks of using such viruses in the long term. For example, would the virus retain its low rate of infectivity and persistence once released in the field? However, further exploration of literature and information available at the time showed that there was an even greater problem. In parallel to the development of the recombinant virus in Spain, Australian scientists had also been working with myxoma virus to insert new genetic material. In this latter case, however, the idea was to insert genetic material that coded for some of the rabbit's own reproductive proteins such as those in sperm or the egg coat protein. A rabbit infected with this recombinant would not only produce antibodies against the myxoma virus but also against its own eggs or sperm. The result would be low fertility or even sterility.

Clearly, each recombinant virus could be quite valuable in its country of origin. The rabbit is a cornerstone in the ecology of Mediterranean shrublands in Europe and many species in Spain and southern France are dependent on it, especially iconic species such as the Iberian lynx (*Lynx pardinus*) and the imperial eagle (*Aquila adalberti*). Thus, enhancing the rabbit population would have great benefit. In Australia, on the other hand, rabbits continue to have a major impact on agriculture and devastate native plant communities and associated fauna and further control is needed. What, Angulo asked, would happen if the Spanish recombinant virus reached Australia or if in the longer term the recombinant viruses being developed in Australia reached Spain. The effects could be devastating.

Naturally enough, Angulo was not alone in thinking about things this way. There were other scientists who also saw the potential conflicts and thought that the matters should be discussed at an international level rather than have each country simply go its own way. One result was a commentary in the *Journal of Molecular Biology* which outlined the dilemma[1]. As we shall see later, it was probably no accident that the paper was written jointly by an enthusiastic young Spanish scientist at the start of a career and an older Australian scientist who had reached that career stage when it was no longer so important to be circumspect in giving a frank opinion.

A second, stronger indication that scientists were prepared to confront these issues comes from the work of Robert Henzell in the Animal and Plant Control Commission in South Australia and Elaine Murphy from the New Zealand Department of Conservation. They organized an international symposium (Rabbits and RHD: disseminating GMOs and conflicting international objectives, held in December 2003 at the 3rd International Wildlife Management Congress), reported on below, where these issues could be discussed in an open forum. Importantly, they further extended the topic to include the issue of genetic engineering of parasites to control possums (marsupials native to Australia) and house mice.

In the case of Australian brush-tailed possums (*Trichosurus vulpecula*), which are now a major pest in New Zealand, the issues run parallel to those between Spain and Australia. Genetically engineered parasites may benefit New Zealand but what if they crossed the Tasman Sea by design or accident and affected the Australian possum population already driven low by habitat change and fox predation?

A similar dilemma exists regarding the house mouse, considered now to be a hybrid between *Mus domesticus* and *M. musculus*. This species is a major pest in the wheat-growing areas of eastern Australia, and some form of biological control would be beneficial. Nevertheless, there has been surprisingly little consideration of the implications of novel GMOs on the species complex (*M. musculus, M. domesticus, M. castaneus, M. mollisimus*) that occurs naturally across Europe and Asia.

The drive for specific biological agents to control a range of mammalian pests has clearly been increasing in recent years and it is useful to see what is influencing the research into these products and ask whether this research is expansive enough to answer the questions about safety posed by Angulo & Cooke[1]. Specifically:

- What is the potential for the escape and establishment abroad of these genetically engineered organisms?
- What are the international risks at scientific, economic and environmental levels?
- Can we develop effective international regulation of their use?
- Can they be modified to make them safer?

The remainder of this article draws from contributions to the international symposium.

The Need for New Biological Agents to Manage Mammal Populations

The benefits of biological agents are well demonstrated in inland Australia where the release of myxomatosis lowered rabbit populations and enabled a pulse of regeneration of shrubs in the 1950s. Nevertheless, with the attenuation of the virus and the build-up of genetic resistance to myxomatosis among the rabbits these effects were temporary. In addition, there is increasing awareness of the subtle effects of rabbits and even with the combined use of myxoma virus and RHD virus rabbits continue to impede regeneration of natural vegetation. Robert Henzell (Animal and Plant Control Commission, South Australia) used rabbit-proof plots to show that even where rabbits are barely detectable, they can still remove about half the seedlings of arid-zone acacias. Their influence on shrub and tree recruitment in the southern rangelands of Australia means that the natural woodlands are still declining. Given the enormous areas involved and the high cost of mechanical control relative to the productivity of the land there are few ways of remedying this problem without recourse to additional biological control measures. This is particularly important as we know that there has been steady development of genetic resistance to myxoma virus among rabbits and we cannot predict how long RHD virus will remain highly effective. Certainly any agent that reduced the effectiveness of the myxoma virus or RHD would be disastrous, returning inland Australia to the dismal conditions experienced in the rabbit's heyday.

In Spain as well there remain equally strong arguments for managing rabbits but in this case the rebuilding of populations for conservation and hunting is the goal (Roger Trout, Forest Research, UK). From a conservation perspective over 41 species of terrestrial and avian predators rely on rabbits to some extent and some species such as the Iberian lynx has been reduced to fewer than 200 individuals following the spread of RHD. Imperial eagles are estimated to number 150 pairs. Nevertheless, half of the funding for research and development of the recombinant virus has come from hunting organizations in Spain (Sanchez Vizcaino, personal communication). A disseminating GMO to protect rabbits against myxomatosis and RHD, both of which are exotic to Spain, has been field tested on one of the Balearic Islands (Juan Barcena, Centro de Investigación en Sanidad Animal, Spain).

Interestingly, the Spanish perspective on rabbits is not shared throughout Europe (Roger Trout). In Britain for example, rabbits cause about UK£120 million worth of damage to agriculture each year, but at the same time they are regarded as being important for maintaining certain types of vegetation, especially heavily grazed swards which offer specific habitats for rare plant and insect species. A genetically modified virus that could not be precisely used without fears of farm income loss or conflict over conservation interests would not be welcomed.

The brush-tailed possum was introduced from Australia into New Zealand in the 19th century and has spread to become a major pest (Phil Cowan, Landcare Research, New Zealand). Not only does it defoliate forest trees that evolved in the absence of mammalian browsers but it is also a predator of nesting birds. Economically it is important because it is a major carrier of tuberculosis (Tb), impeding the eradication of this disease from cattle and consequently limiting access to international markets in dairy products. About NZ$54 million is spent annually on a national management strategy to eliminate possums but a stalemate has been reached where little further progress is being made. There are three options at this stage: the development of possum-specific poisons, the development of vaccines against Tb, and biological controls using GMOs.

House mice introduced into Australia with early European settlement are a serious problem in wheat-growing areas, above all when plagues occur potentially affecting human health and livestock management as well as contaminating grain for export. A GMO based on the murine cytomegalovirus (icMCMV) is at an advanced stage of development for potentially controlling mice and averting plagues (Kent Williams, CSIRO Sustainable Ecosystems, Australia).

Genetically Modified Organisms

Although the first GMO to be developed for managing a mammalian species was the myxoma virus modified by Spanish scientists, it is clear that there are many additional possibilities including the cytomegalovirus (icMCMV) mentioned above.

Nevertheless, viruses are by no means the only possibility. Warwick Grant (AgResearch, New Zealand) described recent work on the nematode *Parastrongyloides trichosuri* that infects the brush-tailed possum showing that it can be readily maintained *in vitro* in laboratory cultures because it has a free-living stage in soil in addition to its better known cycle as a parasite in possums. The ability to maintain it in laboratory culture has enabled it to be genetically transformed to express the products of introduced marker genes, opening up the way for using it to carry other genes so that it will act as an immunocontraceptive agent. Nematodes may have some advantages over viruses in this sense because they show a range in pathogenicity and variations in the extent to which they provoke the immune response. For example, they frequently establish chronic infections, which might keep antibodies that cause sterility high for long periods. Hosts are also susceptible to re-infection.

Consideration of International Risks

The consideration of the risk that GMOs could be spread inadvertently or directly to other countries still remains very limited. For example, the risk assessment that genetically modified *P. trichosuri* could be transported to Australia seems to be largely based on its biological attributes. There seems to have been only one transfer to New Zealand in the 150 years that possums have been present there and the parasite is still restricted mainly to the North Island of New Zealand despite the fact that possums occur extensively on both islands: in the South Island the parasite is restricted to two small areas, one of these being the result of a recent experimental introduction (Mark Ralston, AgResearch, New Zealand). It is also assumed that the relatively low density of possums in Australia would mean that the rate of spread of a transgenic nematode would be slow. However, this does not take into account the possibility of direct human transfer if the genetically modified nematode showed promise as a possum control agent. Although possums have generally declined in rural Australia, individual citizens in urban areas nevertheless hate possums passionately for the damage they cause to ornamental garden plants and fruit trees, and for the excreta they deposit in the roof cavities of houses.

The history of unauthorized introductions of myxoma virus to Europe, and RHD virus to New Zealand must raise a note of caution (Robert Henzell). Additionally, the use of data from Europe to assess risk of virus escape when testing RHD virus on Wardang Island in South Australia proved to be inadequate. The virus not only escaped from the island but spread rapidly over large areas and has since persisted in low-density rabbit populations.

In the case of a genetically modified myxoma virus it is also essential to remember that the myxoma virus itself originated in the Americas and is a natural pathogen in cottontails and their kin (*Sylvilagus* spp.) The risk that genetically modified myxoma viruses might pose in the American situation should not be overlooked.

If house mice in Australia are in fact hybrids then the safety assessments of any GMO must include its species specificity with other rodents as well as considering other genetic groups within the *Mus* species complex. Kent Williams has recently considered the risk of inadvertently exporting icMCMV from Australia in grain shipments containing a few live mice. Such models are complex because the risk that the GMO will spread is assumed to depend on house mouse numbers and anticipates that, if the virus is useful, it will suppress mouse plagues and so limit the risk of spread through the ports. The risk is further dependent on which countries receive the exported grain.

There appears to have been little consideration of the risk of transfer of genetic material from a GMO to another wild-type organism of the same or a related species. Viruses infecting the same cell could interchange genetic information resulting in novel combinations. In the case of sexually reproducing nematodes, there could be direct recombination of genes in hybrid offspring.

How Do We Reduce the Risks Associated with the Use of GMOs?

In a technical sense more might be done to improve the safety of GMOs. For example, it might be possible to design a recombinant virus that only expresses its effects in the presence of specific environmental elements, such as a chemical (Robert Henzell). Similarly, the complex life history of GMO nematodes, or viruses dependent on transfer by specific vectors such as rabbit fleas might make it difficult to transfer them accidentally or even deliberately without high levels of skill or knowledge. It might be possible to build complex genetic devices into GMOs as a means of immunizing susceptible hosts against erroneous use.

Nevertheless, scientific responsibility is a relative concept. Research funders and donors wish to see results for their investments and scientists wish to continue within their appropriate field for the sake of their career development. Not all scientists have appropriate skills to consider matters such as the social aspects of GMO release nor do they have experience in all situations where GMOs might be applied.

National legislation provides guidance but it is unlikely to be far reaching in terms of international responsibilities. For example, the testing of the Spanish genetically modified myxoma virus in the Balearic Islands was done without the fullest possible consultation within Spain. There was no formal consultation with other European countries despite their interests in rabbit management. The conditions set for those island tests appear to have been of a lesser standard than those that would have been required in the UK. Experience with the escape of RHD virus from testing facilities on Wardang Island shows how careful we must be in assuming that a virus apparently spread by rabbit-to-rabbit contact or fomites (objects that transmit infectious material) in Europe would be similarly restricted in a new environment.

At an international level new methods are needed to deal with GMOs that could act on a continental scale and are not necessarily easy to manage at a national level. However, international regulations are limited because the Right of Sovereignty is recognized and individual states retain a great deal of independence. Most international rules are really only advisory precautions as a step towards establishing agreed rules in the longer term.

Yet some basic points remain very clear. Elaine Murphy (Department of Conservation, New Zealand) and David Dall (Pestat Ltd, Australia) pointed out that we have three simple options. Go ahead and act as individual states, refrain from action and possibly forgo the potential benefits of using GMOs in wildlife management, or consult to see if a way can be found through the real and perceived problems inherent in managing animal populations in this way. The mood of the symposium favoured obtaining cooperative outcomes and avoiding retaliations. Nevertheless, establishing groups to facilitate consultation between countries will require elements of diplomacy as well as scientific understanding. Implicit in this approach is the idea that to progress we will need to manage risk because we cannot move ahead if we insist that all GMOs will be so well known and the outcomes of their use will be so predictable that there should be no risk. There is a certain tension in the decision to move forward.

It was reported at the symposium that the Office International des Epizooties (OIE) at its scheduled meeting in May 2004 was to consider how to manage these risks. The OIE's Working Group on Wildlife Diseases considered this issue again in February 2004, and the result was a recommendation to proceed with considerable caution. While the working group recognizes the potential utility of disseminating GMOs to manage wildlife crises, it believes that the particularly important risks in creating disseminating GMOs necessitate high standards for their development and the absence of possible alternative strategies. GMOs targeted at contraception appear to be a special case and require particularly high safety testing standards. Safety standards must include the global environment, and not just the local environment. Arrangements to manage the risks of developing and using disseminating GMOs to manage wildlife may involve both the OIE and the Cartagena Protocol on Biosafety.

There are encouraging signs that at least one organization developing disseminating GMOs recognizes that the international risks need to be managed effectively and transparently. The bid for a successor organization to Australia's Pest Animal Control Cooperative Research Centre includes a project to address these risks.

Readers may have an opportunity later this year to discuss this topic and make their views known in an online conference, hosted by the Convention on Biological Diversity's Biosafety Clearing-House[2].

[1]Angulo, E. & Cooke, B. (2002) First synthesize new viruses then regulate their release? The case of the wild rabbit. *Molecular Biology* 11, 2703–2710.

[2]Convention on Biological Diversity's Clearing-House Mechanism:
www.biodiv.org/chm/default.aspx

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For a previous article on this issue, see BNI *23(4), 89N–96N (December 2002), Rabbits and Possums in GMO Potboiler.*

IPM Systems

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

Flying Start to Area Wide IPM in Hawaii

High-value export horticulture is thriving. Whatever the season, supermarket shelves throughout the world overflow with exotic fruit and vegetables. Many tropical countries have seen their export earnings rise as a result, yet that icon of tropical islands, Hawaii, has been missing out on the bounty. With fertile soil and a climate that can produce 4–5 crops per year, Hawaii would be cashing in were in not for a suite of invasive alien fruit flies, which has severely impacted development of a thriving fruit and vegetable industry. In the last 3 years, however, the innovative Hawaii Area Wide Fruit Fly Integrated Pest Management (HAW-FLYPM) programme has begun to restore hope to growers: they have seen fruit fly numbers decrease and are beginning to replant susceptible crops.

Fruit flies are undoubtedly the most serious constraint to Hawaiian agriculture.

- Damage from fruit flies is estimated to cost the industry more than US$300 million annually in lost local markets. Crops that could otherwise be grown locally, such as tomatoes, cucumbers, melons and zucchini, are often imported to meet demand.
- The value of lost export markets is incalculable. Increased export regulations mean fruit fly damaged fruit and vegetables do not meet state and federal requirements for export to continental (US) and international markets.
- Countries currently free of fruit flies and anxious to protect their own industries from these invasive pests place quarantine restrictions (frequently bans) on imports from infested countries such as Hawaii.

There are four invasive alien fruit fly species of economic importance in Hawaii. They are widespread and occur from sea level to over 2000 m above sea level. Their dates of introduction stretch back over a hundred years:

- Melon fly (*Bactrocera cucurbitae*) was introduced in 1895.
- Mediterranean fruit fly or medfly (*Ceratitis capitata*) was introduced in 1910.
- Oriental fruit fly (*Bactrocera dorsalis*) was introduced in 1945.
- Malaysian (solanaceous) fruit fly *(Bactrocera latifrons)* was first found in Hawaii in 1983.

To produce a viable fruit or vegetable crop in Hawaii may mean spraying almost weekly with organophosphate or carbamate insecticides at considerable economic and environmental cost, and many farmers have abandoned susceptible crops altogether. According to the United States Department of Agriculture – Agriculture Research Service (USDA-ARS), the four species of fruit flies attack over 400 different host plants, including economically important crops such as citrus, coffee, guava, loquat, mango, melon, papaya, passion fruit, peach, pepper, persimmon, plum, star fruit, tomato and zucchini. As a result of the invasive pests, Hawaiian agriculture became heavily reliant on non-susceptible crops such as sugar cane and pineapple but the importance of these crops has declined in recent years, giving a new impetus to fruit fly control as susceptible crops have once again become the backbone of Hawaii's agricultural sector.

Past control efforts focused on eradication. Fruit fly species have been successfully eradicated elsewhere (e.g. Australia, Cook Islands, Florida and California) but all attempts in Hawaii have failed. One hurdle for the new project was to re-engage with growers disenchanted by these previous ineffective measures. HAW-FLYPM began in 1999 with a US$750,000 federal grant on Oahu, Maui and Big Island. Key features of the initiative are:

- It is a user-focused programme.
- It focuses on keeping pest damage below an economically significant threshold rather than attempting eradication.
- It has built extensive partnerships. USDA-ARS (lead), the Hawaii Department of Agriculture and the University of Hawaii make up the core team, with USDA-APHIS (Animal and Plant Health Inspection Service), the IR-4 Program and industry participants. In addition, it has engaged with growers and home gardeners.
- It aims to be environmentally beneficial, reducing the amount of pesticides used by growers and minimizing risk to native Hawaiian biodiversity – of particular concern is Hawaii’s complex of native fruit flies.
- It is creating a user-friendly IPM package whose use will endure beyond the end of the programme.

Typically for an IPM programme, the package includes a combination of components. Both control and monitoring are important and the varied techniques that have been developed illustrate the breadth of inter-disciplinary synergies that underpin the HAW-FLYPM programme.

Suppression Techniques

• *Field sanitation to break the cycle of reproduction.* Rotten fruit are ideal breeding sites. Rotten and infested fruit are removed from the field and placed in bins, barrels, plastic bags and deep pits or inside small tents made of a mesh-like material to reduce the build up of fruit fly populations.

• *Male trapping.* Mass trapping using chemical attractants for luring male flies has been developed. Traps are placed uniformly throughout breeding areas to provide area-wide suppression. Attractants applied in traps on fibreboard blocks or in a gel formulation can remain effective for several months.

• *Low-risk insecticide with a protein bait.* ARS research in Hawaii and Weslaco, Texas led to the development of Spinosad, produced by the soil-dwelling bacterium *Saccharopolyspora spinosa.* This is deployed in an attractant-based protein bait spray, called GF-120. It is applied as spots at low volumes in growing areas and on border crops in place of the more environmentally toxic organophosphate malathion.

• *Sterile male release.* Male flies are sterilized through irradiation and then mass released into the wild, where they mate but no progeny are produced. This approach overfloods the breeding population with sterile flies, causing the reproductive rate of the population to decline.

• *Augmentative biocontrol.* An important parasitoid of medflies and oriental fruit flies, *Biosteres arisanus*, is being mass reared by ARS and released to increase mortality in fruit fly populations. Biological controls work best in ecologically balanced agroecosystems, which the HAW-FLYPM programme is promoting.

Population Monitoring

• *Baseline trapping.* Male lures and food-based attractants are used to monitor fluctuations in populations of the four species of fruit flies in and around agricultural cropping areas.

• *Grid trapping.* Sites on all three islands were identified for further grid trapping. Each site includes a target agricultural area plus surrounding areas. Male lure traps are placed in every square kilometre to identify fluctuations in species populations within a 40–50 km^2 grid.

• *Host mapping and infestation monitoring.* Wild and cultivated host plants of fruit flies within the grid area are identified and mapped using GPS/GIS, and relative infestation levels throughout each grid are evaluated.

Growing Support

While interactions between scientists created the IPM package, the successful relationship that the researchers built with the growers and residents of Hawaii is at the heart of its success.

To test and fine-tune the HAW-FLYPM programme, the team needed cooperators: individual growers who would allow research to be conducted on their farms, which could then be used as demonstration sites. Initially, as noted above, growers were inclined to be sceptical of yet another fruit fly control effort, especially as they were putting themselves at economic risk by applying experimental technologies rather than tried-and-tested insecticides. Concerted efforts by extension agents, ARS researchers and Hawaii Department of Agriculture staff to explain the IPM approach to grower groups included videos, brochures, newsletters and a website to make information more accessible. But above all, the HAW-FLYPM team considers that personal communication with growers has been the real basis for the programme's successful adoption. Fine-tuning the IPM package meant weekly visits to cooperators' farms to monitor fruit fly populations, and these visits could be combined with training sessions to adapt the system to the individual farm. The goal is to give the farmers the knowledge to make their own decisions.

Just 3 years into the programme, there are signs that the fruit flies that emerged as a serious threat to Hawaii's agriculture a century ago are beginning to be beaten. One large diversified farm on Oahu has cut insecticide use by 60–70% and has been able to diversify its crops. In one targeted area on Big Island, melon fly infestation has been reduced from 30% to 5% and organophosphate use has been cut by more than 60–70%. One grower reports that fruit fly populations on his farm have fallen by 65%, while profits have increased. He and others are beginning to experiment with fruit long discounted as too susceptible to fruit flies to be worth planting. A prime example is persimmon, a popular fruit crop in Hawaii: many orchards were abandoned as the fruit fly problem worsened, but trees are now being replanted and harvests are increasing. Another grower reports that crops, such as zucchini, that were previously only profitable during the winter season can be grown profitably throughout the year using the IPM package. Successes like these mean that the first cooperators recruited to the HAW-FLYPM programme are happy and more growers are now willing to try adopting the IPM package as word spreads.

Gardeners Complete the Picture

Increasing adoption is important for the long-term success of fruit fly control. Area-wide suppression is more important than control on individual farms for managing mobile pests such a fruit flies. Uptake by more and more farmers is encouraging but many of the fruit fly-susceptible host plants are also grown in household gardens, which can serve as reservoirs. In them, fruit fly populations can build up and then re-infest neighbouring IPM-managed farms. The HAW-FLYPM programme has therefore also recruited home gardeners in Kohala – senior citizens in particular. In this pilot study, participating gardeners are encouraged to practise sanitation, and monitoring traps are placed in their gardens to see the impact of IPM in this context. Eventually, these gardens may serve as demonstration plots to recruit more gardeners to the programme. Scientists plan to tailor the IPM package to be user-friendly and inexpensive so that gardeners all over Hawaii adopt it.

Quarantine Apart

Although the HAW-FLYPM package has been demonstrated to reduce pest fruit fly populations below economically damaging levels, quarantine measures taken by other states and countries remain an impediment to the complete rehabilitation of Hawaii's fruit and vegetable export sector. Bans imposed by importing countries are understandable. In California, for example, invasion by fruit flies could result in losses of some US$1.4 billion annually.

With the success of the IPM programme, fruit fly populations in Hawaii are beginning to fall. If they fall far enough, complete eradication may even become a possibility. Thus, a programme that grew out of failed eradication attempts may open the way for permanent eradication of invasive alien fruit flies from Hawaii and open the mainland US and international markets again to the Hawaiian fruit and vegetable industry.

For the moment the HAW-FLYPM programme is focusing on making fruit fly IPM sustainable. This will improve the profitability of land under production and allow new areas to be planted, which in turn will provide more employment possibilities, lead to a greater self-sufficiency in food production and make agriculture a stronger component of the Hawaiian economy.

Sources: Kaplan, J.K. (2004) Fruit flies flee paradise. *Agricultural Research* February 2004, pp. 4–9. www.ars.usda.gov/is/AR/archive/feb04/flies0204.htm

HAW-FLYPM: www.fruitfly.hawaii.edu/programbackground.html

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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.

Pacific Regional Food Security Programme

This year is seeing the expansion of a participatory programme in which Pacific island countries and territories are addressing their food security issues through mainstreaming sustainable agriculture into their national agricultural activities.

The ten African, Caribbean, Pacific island (ACP) countries of Fiji, Kiribati, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu and the French Overseas Territories of French Polynesia and Wallis and Futuna have been participating in the Development of Sustainable Agriculture in the Pacific (DSAP) programme since its inception in 2003. Funded by the European Community and implemented by the Secretariat of the Pacific Community (SPC), DSAP provides funding that enables the participating countries to implement activities at national level that will help with food security through sustainable agriculture. In early February 2004, the European Union Commissioner, Mr Paul Nielsen, signed an agreement that allowed the six new ACP countries of Cook Islands, Niue, Marshall Islands, Nauru, Palau and Federated States of Micronesia to join the DSAP programme.

The Regional DSAP programme features:

- *A participatory approach.* This involves listening to the farmers' needs, identifying their problems and using appropriate technology and resources to work with the farmers in solving their problems. The results from Participatory Rural Appraisals (PRAs) largely determine national workplans and activities.
- *Guidance at country level.* This is provided by a National Steering Committee (NSC) comprising partners and stakeholders in agriculture. It includes NGOs working in local communities, other government departments, educational institutions, women's groups, youth groups and farmers themselves who represent farmer groups.
- *Partnerships, collaboration and synergies.* At regional level, DSAP works with other sections within SPC to deliver services. Whether it is the SPC Plant Protection Services for advice on agricultural pests and diseases or the Animal Health Unit, DSAP seeks the services of other sections within SPC to respond to identified farmer needs.
- *National capacity building in extension.* This will enable extension officers to identify farmer problems in a participatory manner, ensuring that the farmers' interests are at the centre of the solution. DSAP will also strengthen national capacity to produce extension information and ensure that the information is communicated effectively and is accessible to farmers. Sharing lessons, ideas and information about sustainable agriculture is central to DSAP activities.

For the ten countries that have been participating in the DSAP programme so far, national activities include establishing crop/tree nurseries, improving soil fertility, supporting small-scale agriculture industries, supporting institutional agriculture development, providing and distributing planting materials, and conducting and supporting on-farm trials.

With the commitment shown by the ACP island countries to the DSAP programme and the addition of six new countries, the Pacific region with its susceptibility to natural disasters, impacts of climate change, increasing populations and health related diseases is leading the way to ensure sustainable island livelihoods.

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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.

Aphid and Coccid Biocontrol

An IOBC (International Organization for Biological Control of Noxious Animals and Plants) International Symposium on Biological Control of Aphids and Coccids is being held at Tsuruoka, Japan on 25–29 September 2005. The symposium is organized by Yamagata University with support from the Japanese Society of Applied Entomology and Zoology, the Entomological Society of Japan, the Japanese Ecological Society and the Society of Population Ecology.

Aphids and coccids are major agricultural pests worldwide, and have similar groups of natural enemies. Biocontrol programmes have had variable success, with those directed against coccids having more success. The ecological and evolutionary basis to this variability is poorly understood. The aim of the symposium is to explore differences and similarities in the ecology of aphidophagous and coccidophagous insects and their interactions with their hosts. Sessions will be held on the following themes:

- Natural enemy augmentation in protected cultures
- Conservation and promotion of natural enemies
- Environmental risks of natural enemy introductions
- Interactions of ants, homopterans and natural enemies
- Intraguild predation
- Information acquisition and foraging in insect parasitoids and predators

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www.bf.jcu.cz/tix/strita/aphidophaga/main.html

Lantana Monograph

Late last year, ACIAR published a monograph on current and future management of lantana (Lantana camara). It provides both an up-to-date summary of the current situation and also suggestions for future avenues for research, particularly for developing countries that may be able to utilize the efforts of Australian and other workers. The lantana story is a fascinating one, beginning when this American plant was brought to Europe and cultivated as a glasshouse ornamental. Some 650 varieties are now recognized worldwide. Many of the varieties were sent to colonial tropical and subtropical countries, which ultimately contributed to lantana becoming one of the world's major weeds. Interestingly, the book points out that there are 27 countries with favourable climates that do not yet have lantana and that an obvious strategy for these countries is to make very sure that it is not imported. Lantana was the earliest target for a fully-fledged biocontrol programme, which began with Hawaiian efforts in Mexico in 1902. Since then some 40 agents have been tried somewhere around the globe. These agents are described; often with very good photographs.

This book is intended as a tool for everyone involved in lantana control as well as weed biocontrol scientists in general. Since 1902, millions of dollars and many years of work have gone into searching for potential biocontrol agents and introducing them to the countries where lantana is a weed. This book brings together the available information about lantana and the insects and diseases that have been studied to control it. The authors discuss possible factors influencing the success or failure of these agents, potential new research areas and make recommendations for future research directions

Day, M.D., Wiley, C.J., Playford, J. & Zalucki, M.P. (2003) Lantana: current management status and future prospects. Canberra Australia, ACIAR, MN102 2003.128 pp. Price: Aus$44.

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Also downloadable as three pdfs at:
www.aciar.gov.au/web.nsf/doc/ACIA-5TD6JV

Renewable Agriculture and Food Systems

The first issue of Renewable Agriculture and Food Systems from CABI Publishing was published in February 2004. The journal, formerly the *American Journal of Alternative Agriculture*, aims to reflect the transition to an agriculture that utilizes food production and distribution systems relying less on non-renewable petrochemical resources, and more on renewable sources. John W. Doran, Editor-in-Chief, explains that the changes in the journal are intended to advance the goal of creating a common ground where scientist, educators, policymakers, farmers, and other practitioners of various perspectives and view points can share their research and ideas.

Have Your Say

The new journal also has a forum section that will present lively discussions, from differing viewpoints, on new or provocative topics. The first forum, in the March issue of *Renewable Agriculture and Food Systems*, concentrated on the subject of 'Local food, local security.'

Submit a paper to: Renewable Agriculture and Food Systems, c/o Emma Durman, CABI Publishing, Nosworthy Way, Wallingford, Oxfordshire, OX10 8DE, UK.
Email: rafs@cabi.org

Contact the Editor-in-Chief: John W. Doran, USDA-ARS, 116 Keim Hall, University of Nebraska, Lincoln, Nebraska, NE 68583-0934, USA.
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ANBP Welcomes Practitioners

A new 'practitioner' category of membership for the Association of Natural Biocontrol Producers (ANBP) is aimed to attract people and/or businesses engaged in the application of macrobial biocontrol organisms (i.e. insect or mite parasites, predators and/or entomopathogenic nematodes), consulting, research, education and pest management.

The ANBP's mission is to address key issues of the augmentative biological control industry (which utilizes beneficial insects, mites and nematodes to manage agricultural, horticultural and plant pests) through advocacy, education and quality assurance. It holds annual meetings, publishes a newsletter, *Biocontrol Matters*, which provides a forum to address issues facing the biocontrol industry, and hosts a website providing information on the availability and use of natural enemies.

The association believes the new category of members will strengthen ANBP by increasing membership and adding a new perspective tuned to the end-user. The annual fee for practitioner membership is US$125.

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Whitefly and Bollworm Bibliographies

A complete listing of the world literature of the sweetpotato/silverleaf whitefly (*Bemisia tabaci/ argentifolii*) and the pink bollworm (*Pectinophora gossypiella*) is maintained at:
www.wcrl.ars.usda.gov/biblios/biblios.html

These bibliographies include journal articles, proceedings, books, book chapters, local, regional and national reports, and popular press articles. Both bibliographies are updated annually in February. The 2004 editions are now available for download and on-line searching.

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Danish Biocontrol Centre

The establishment of a Danish Centre for Biological Control (DCBC) is aimed at strengthening biocontrol of pests, diseases and other noxious organisms in agriculture and animal husbandry in Denmark. The initiative is a joint venture between the Royal Veterinary and Agricultural University, the Danish Institute of Agricultural Sciences, the Danish Pest Infestation laboratory, the National Environmental Research Institute and the National Institute of Occupational Health, with financial support provided by the Danish Research Councils.

Activities will focus on workshops for the development and practical use of biocontrol, and environmental and work-related risks. The centre aims to enhance Danish participation in international cooperation.

Source: IWSN Newsletter No. 18 (January 2004)
www.whitefly.org

Biobest Side Effects Manual Updated

Biobest have produced an updated version of their manual on the side effects of crop protection products on bumblebees and natural enemies. This fourth edition includes revisions to make it more user-friendly (excluding less relevant/redundant information, species entries separated/grouped according to side effects, etc.), adds new information for products listed in previous editions and entries for new products. It provides the most comprehensive and accurate overview of the direct side effects of crop protection products on bumblebees and natural enemies used by the horticultural industry. Results were verified in trials under field conditions. The publication has used in-house research, outputs of the IOBC Working Group 'Side Effects of Pesticides on Beneficial Organisms', information drawn from published literature and pharmaceutical industry trials, and material submitted by researchers throughout the world.

An online version can be viewed free at:
www.biobest.be

For the printed version (cost: €6 + P&P) contact:
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