The Natural Control of **Japanese Knotweed**

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Agenda

Thursday 23 July 2009

Defra, Nobel House, London SW1P 3JR

Morning Session

9.30 am	Registration and morning tea
10.00 am	Introduction and welcome by **Cllr Julian German**, Cornwall Council's Environment Portfolio Holder and **Steve Crummay**, Living Environment Manager, Cornwall Council, Chair of the Japanese Knotweed Research Project Board
10.30 am	Background to the problems and costs associated with Japanese knotweed by **Trevor Renals**, Environment Agency's Invasive Species Adviser
11.00 am	Presentation of the scientific research by lead scientist, CABI's **Dr Dick Shaw**
12.00 noon	Question and Answer session
12.30 pm	Buffet lunch and an opportunity to talk informally to the project board and research team
1.30 pm	Afternoon session begins (the agenda will be handed out at registration)

Speaker biographies

Steve Crummay – Living Environment Manager, Cornwall Council
(Chair of the Natural Control of Japanese Knotweed Research Project Board)

Steve Crummay has worked in environmental and conservation management for over 25 years, including time spent with the National Trust and several local authorities. Throughout his career he has been involved in development and delivery of many innovative projects and initiatives including the Tarka Project in Devon, the development of some of the UK's first Marine Conservation Areas in Cornwall's inshore waters, the development of the first Local Authority Local Area Agreement (LAA) that directly addresses biodiversity issues as well as the natural control of Japanese knotweed national research project developing potential natural control methods for Japanese knotweed. He sits on numerous County, regional and national consultation and advisory groups.

In his current post he manages Cornwall Council's Living Environment Section that was established with the formation of the new unitary authority in Cornwall, and is responsible for the strategic core elements of sustainability, access, conservation, enhancement and promotion of the environment throughout Cornwall. Through its work, the Section seeks to ensure that Cornwall's environment is conserved, and wherever possible enhanced, so it can continue to be enjoyed and contribute to the economic and social well being of the County whilst at the same time is adapted to face the challenges presented by a changing climate.

Trevor Renals – National Advisor for Non-Native Species, Environment Agency

Trevor has managed ecological monitoring in Cornwall for the Environment Agency and its predecessor organisations since 1989. He was co-instigator of the Cornwall Knotweed Forum in 1997. The forum has provided a model that has been used throughout the UK to organise local action against the spread of invasive non-native species. He is the author of the Environment Agency's 'knotweed code of practice'. This code has provided developers with the guidance they need to manage Japanese knotweed waste in an effective and economic fashion, thus reducing waste and environmental impact. Trevor has been involved with the Japanese knotweed natural control programme since the beginning of the research. He is currently the national advisor on non-native species for the Environment Agency.

Dr Richard (Dick) Shaw – Principal Investigator, CABI

Dr Richard (Dick) Shaw has been working on the biological control of weeds for 15 years and is currently the project manager and principal investigator for the knotweed project. Dick is a field entomologist by training and now focuses on the biological control of temperate weeds, in particular for aquatic and riparian weeds. This has taken him on fieldwork to 14 countries where he has planned and executed countless natural enemy surveys as well as supervised numerous staff and students. His experience means he is a regular invited speaker at regional, national and international conferences.

Executive Summary

The problem

Japanese knotweed is one of the most damaging invasive species to arrive in the UK, continental Europe and the USA, and is capable of growing three metres in as many months. It was introduced from Asia to Europe in the early to mid-19th century as an ornamental plant. In its native Japan, the plant presents little or no problems due to natural controls that have evolved to co-exist alongside and provide a natural brake on its spread. But in Britain, it is now deemed to be one of the worst invasive species. This is due to its vigorous nature, the damage it causes to buildings, paving, archaeological sites, riverways and railways. It also harms our native biodiversity, excluding our British plants by its dense growth.

The cost to the UK economy is also great. In 2003, the Government put the cost of control, if attempted UK-wide, at over £1.5 billion. Since then, both the cost and the problem have grown. These control methods rely mainly on chemicals and have been deemed unsustainable and unsuitable for a national eradication programme. A longer-term solution to the problem is required.

The Natural Control of Japanese Knotweed Research Project Board

In 2001, a consortium of partners was brought together to form a project management board, which has managed a scientific research programme examining the potential for the natural or biological control of Japanese knotweed. The following organisations are represented on the board and have been providing the necessary funding for this work: British Waterways; Cornwall County Council; Defra; Department for the Economy & Transport, Welsh Assembly Government; Environment Agency; Network Rail; and South West Regional Development Agency. (For more information on each partner, please see partner section).

Research

CABI is a not-for-profit research institute and has carried out the work on behalf of the board. The research sought to identify a natural enemy of Japanese knotweed that would be suitable for release in Great Britain.

During the six years of the project, CABI considered over 200 possible control agents. The research demonstrated that a sap-sucking psyllid – *Aphalara itadori* – from the plant's native range in Japan, is highly specific to Japanese knotweed and shows good potential for its control in Great Britain. Research shows that the introduction of the psyllid will not adversely affect native biodiversity and could result in a significant reduction in costs associated with tackling Japanese knotweed conventionally through the use of chemicals and physical removal.

For more information, please visit **www.cabi.org/japaneseknotweedalliance**

The Japanese Knotweed Research Project Board

The research institution

CABI

CABI is an international not-for-profit organization that specialises in agricultural and environmental research. Its mission and direction are influenced by its member countries who help guide the activities undertaken as a business. These include scientific publishing, projects and consultancies, providing information for development and mycological services.

CABI has been contracted to undertake research on behalf of the project board. CABI scientists have been conducting research into potential natural control agents to combat Japanese knotweed since 2000. This work entailed the collection, identification and selection of natural enemies of Japanese knotweed. Potential agents were assessed in their Defra-licensed quarantine facility and all work is carried out according to international protocols. **www.cabi.org**

Project management partners

Defra

The Department for Environment, Food and Rural Affairs' role is to help enable people to live within their environmental means. Defra's priority is to ensure that the resources we need and environment we enjoy continue to be available for us all, now and in the future.

Defra holds policy responsibility for non-native species, and its Food and Environment Research Agency (Fera) holds policy responsibility for plant health and is also the licensing authority in England. Defra and Fera are working together, and in liaison with Welsh colleagues, to ensure that a scientifically rigorous licensing process is followed before any licensing decision on the release of a natural control agent for Japanese knotweed. **www.defra.gov.uk**

Environment Agency

The Environment Agency is the leading public body for protecting and improving the environment in England and Wales. Its job is to make sure that air, land and water are looked after by everyone in today's society, so that tomorrow's generations inherit a cleaner, healthier world.

The Environment Agency is committed to improving the ecological quality of our water environment. It is also responsible for managing flood risk. River corridors dominated by a dense monoculture of Japanese knotweed damage biodiversity and reduce the capacity of the watercourse to cope with floodwater. It also reduces the amenity value of the river and its aesthetic value to the local community. Currently, herbicides are used to manage Japanese knotweed. The Environment Agency seeks a safe, specific and sustainable alternative that will pose no risk to water quality or the wider environment. **www.environment-agency.gov.uk**

Welsh Assembly Government

The Welsh Assembly Government aims to ensure the development of 21st century Wales as a self-confident, prosperous nation, committed to social justice and sustainability. Accountable to the National Assembly for Wales, it offers a progressive agenda for improving quality of life for all communities, including measures to support the Welsh language.

The former Welsh Development Agency (WDA), now part of the Welsh Assembly Government's Department for the Economy and Transport, provided funding to conduct research into a natural control for Japanese knotweed. The WDA was one of the founding members of the research programme and the alliance. Funding for some of the preliminary research phases which has led to the current successful phase of work also came from Wales. Japanese knotweed has a huge economic cost to development and regeneration in addition to the impacts on biodiversity and landscape. The costs of eradicating Japanese knotweed from a site due to be developed can be extremely significant, particularly South Wales which is one of the worst affected areas in the UK. The Welsh Assembly has worked in partnership with a variety of other UK-wide funding bodies to support this research by CABI into the natural control of Japanese knotweed. **www.new.wales.gov.uk**

South West Regional Development Agency

The South West Regional Development Agency leads the development of a sustainable economy in South West England. The Agency's core strategy is focused on creating the conditions for productivity-led growth.
www.southwestrda.org.uk

Network Rail

Network Rail is the 'not for dividend' owner and operator of Britain's railway infrastructure, which includes the tracks, signals, tunnels, bridges, viaducts, level crossings and stations – the largest of which we also manage. Their aim is to provide a safe, reliable and efficient rail infrastructure for freight and passenger trains to use.

Network Rail is working hard to create a lineside environment in order to run a safe and reliable railway, incorporating open space, grassland, low-growing shrubs and trees. Japanese knotweed undermines Network Rail's efforts owing to its fast, voracious growth rate, and it can cause damage to buildings and embankments while out-competing native species. Successfully controlling Japanese knotweed takes up valuable resources in terms of time and money – resources that could be better spent elsewhere on maintaining and improving the railway. **www.networkrail.co.uk**

Cornwall Council

Cornwall Council is Cornwall's largest democratic organisation and is focused on providing a strong and sustainable community for one and all. It aims to do this by improving individual development and well being, fostering the success of all communities, enhancing the living environment, promoting Cornwall to the world, being a strategic, ambitious, accountable and well-managed Council, providing leadership and delivering services.

Cornwall Council, on behalf of the Natural Control for Japanese Knotweed Project Board, is responsible for the co-ordination of the project. It is hoped that this research will identify another control method to complement and, in some cases, replace existing treatments. **www.cornwall.gov.uk**

British Waterways

British Waterways cares for 2,200 miles of historic canals and navigable rivers, working to ensure that the 200-year old network continues to benefit the nation now and into the future. We work with a broad range of public, private and voluntary sector partners to unlock the potential of the inland waterways and generate income for reinvestment in the network for the benefit of the millions who visit the waterways every year. British Waterways is accountable to the Department for Environment, Food and Rural Affairs (Defra) in England and Wales and to the Scottish Government in Scotland.

Japanese knotweed is one of the most invasive species affecting the waterways in British Waterways' care, choking watercourses and out-competing native species. British Waterways is a founder member of the Japanese Knotweed Project Board and is committed to the search for a sustainable solution to the problem.
www.britishwaterways.co.uk

Japanese knotweed the plant: the problem

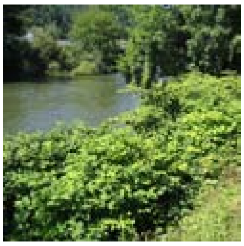
Japanese knotweed is not native to Europe and was introduced to the UK without its natural enemies. In Japan, the plant generally grows in harmony with the environment and is not considered to be invasive.

It has an unfair advantage over native species because the controlling influence of the many insects and fungi that attack the plant in its native range have been removed. These species co-evolved with Japanese knotweed. Our native species on the other hand have not, and very few if any insects or fungi can be found on the plant since its introduction almost 200 years ago.

Japanese knotweed can spread and reproduce from a tiny fragment of rhizome weighing less than a gram. This and its vigour have contributed to this super-weed's success.

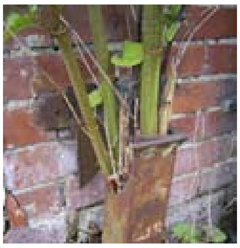
Biodiversity

Japanese knotweed has a significant negative impact on both floral and faunal biodiversity both directly, by not supporting any food webs of note; and indirectly, by displacing native plants that do support a wide array of associated species. Knotweed affects ecosystems by crowding out native vegetation and limiting plant and animal species diversity. Recent studies led by the CABI team in Switzerland have proved that knotweed areas suffer reduced species diversity. They have even found evidence of allelopathy (the release of chemicals that suppress the growth of other plants).



Flooding and water quality

Japanese knotweed increases flood risk by reducing the capacity of river channels to carry flood water. The canes block sluices, weirs and other structures. During winter, the dead canes leave riverbanks exposed and vulnerable to erosion. Shading and the decomposition of leaves are also affecting river quality, as is the lack of insect species which provide food for other aquatic invertebrates and fish. The knotweed leaf litter provides fewer good nutrients to streams than the native vegetation it displaces and this has the potential to alter food chains. Japanese knotweed's impact on water quality may threaten salmon and other fisheries.



Infrastructure and development

Japanese knotweed's stout rhizomes (underground stems) are notorious for pushing through asphalt, building foundations, concrete retaining walls and even drains, causing significant damage. This can add huge costs to development and regeneration schemes (up to 10%). Contaminated soil should be treated as controlled waste due to the plant's ability to reproduce from tiny fragments of root system.

Safety

Japanese knotweed is capable of obscuring railway and road signs and its ability to push through concrete can have serious impacts on infrastructure, including causing trip hazards in paving. The extensive monocultures formed by the weed can also leave areas open to flooding due to the dead canes blocking drainage channels.

Social/human impacts

The presence of knotweed in an urban setting is often an indication of dereliction and is highly unwelcome. It also obscures panoramas in beauty spots and tourist areas. In its preferred riverbank habitat, knotweed can also impede access for recreational activities such as fishing and boating.

Further information

To find out more about dealing with Japanese knotweed please refer to the Environment Agency's code of practice by visiting: www.environment-agency.gov.uk/static/documents/Leisure/japnkot_1_a_1463028.pdf, or refer to the Welsh Assembly Government's guidelines for treatment on construction and development sites "The Eradication of Japanese Knotweed".

For useful guidance on identification as well as householder advice visit:
www.environment-agency.gov.uk/homeandleisure/wildlife/31364.aspx

Aphalara itadori: a potential solution?

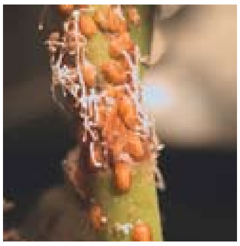
Introduction

The Japanese knotweed psyllid, *Aphalara itadori* is just one of the 186 species of insects found to feed on Japanese knotweed in Japan. "Itadori" is what the Japanese call "Japanese knotweed", so this tiny bug is actually named after its host plant.

Life cycle

After migrating from their winter sheltering sites, the adult psyllids seek out Japanese knotweed plants and begin to lay eggs on the leaves and under node sheaths. These eggs hatch to produce sedentary nymphs which "plug in" to the leaves or stems and suck the fluid out of the plant. As the nymphs feed, they produce a waxy substance. They pass through five growth stages or "instars", before emerging as adults some weeks later. If the temperature is high enough, they can go on to produce another generation before the winter. Adult females can live for up to two months and produce an average of more than 600 eggs in that time.

How do we know what it feeds on?



Aphalara itadori has only been found on its host, Japanese knotweed, in Japan. But, whilst it is possible to draw some conclusions from such field observations, this is not representative of the environment or flora that it will encounter if released in Great Britain. It was therefore necessary to carry out host range testing using 90 selected test plant species (see section on test plant selection for further information). As the nymphs are relatively immobile, the plant on which a female chooses to lay her eggs effectively decides the host for her offspring. During four years of research 98.48% of more than 145,000 eggs were laid on invasive Japanese knotweeds when the adults were given a choice. Those eggs that were laid on non-target plant species were found to be incapable of developing through to adult. As a result, *Aphalara itadori* was unable to sustain a population on any other plants. It was however, possible to force the psyllid to develop to adult if nymphs were manually transferred to wire plant (*Muehlenbeckia complexa*), another invasive plant, although only in very low numbers. We can conclude that this psyllid is a true knotweed specialist.

What damage does it cause?

In the field in Japan we found patches of Japanese knotweed where the psyllid population was high and the plants were suffering quite badly with stunted and deformed leaves. In the laboratory, we have shown that the psyllid is capable of killing small plants at high populations but more often than not, the affected plants are stunted with very small leaves and a reduced surface area.

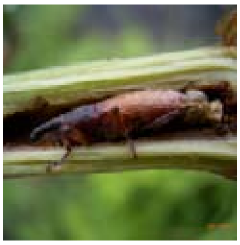
What can we expect?

Classical biological control is a long term approach to weed control, so any major results are likely to take years. It is important to realise that control and not eradication is the end point of successful biological control programmes. The target weed is reduced to an acceptable level and the previous costs and efforts expended in control should be reduced. It is anticipated that attacked knotweed plants will have reduced vigour and their neighbouring plants will be able to re-establish thanks to reduced competition. What we should *not* expect is the complete abandonment of current treatments and this natural enemy should be seen as part of an integrated control programme, not the complete solution.

Rejected agents – some examples

Introduction

The most important aspect of a biological control programme is selecting the best agent for the job. Safety is an absolute priority, so rigorous host range testing that meets international protocols is carried out over many months. During the six years of the research project, over 200 agents were considered and many have been rejected along the way, here are a selection.



Lixus weevil

Lixus elongatus is a stem miner and spends most of its life as a larva within the stems of Japanese knotweed in Japan. After mating, the female chews a hole in the stem and deposits an egg inside which hatches to produce a voracious larva that chews the interior walls of the plant, weakening it and occasionally limiting water movement. Although the weevil was never found on any other plant in the field, it was found to be capable of rearing through to adult on *Polygonum hydropiper*, a native plant in the UK.

Knotweed sawfly

The sawfly, *Allantus luctifer*, was one of the most damaging insects found attacking knotweed in its native range. Unfortunately we found larvae feeding in a Japanese dock plant and host range testing confirmed that it would feed on various native UK *Rumex* species.

***Gallerucida* leaf beetle**

This beetle and its larvae were fairly common on various knotweeds in Japan and until recently taxonomists considered there to be two species. We found larvae feeding on another dock plant and reared them through to adult on this non-target species, so it was rejected. However, it is possible that the taxonomists were right and that one of the two species might have a different plant preference.

Japanese knotweed aphid

The aphid, *Machiatella itadori*, although being named after its host Itadori (meaning takes away pain) uses buckthorn as a winter host, so was not suitable for the UK given the number of native buckthorns. However, this aphid may be of interest to North America, where many buckthorns are considered invasive species.

Endoclyta moth

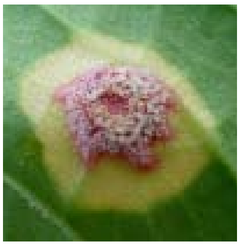
This root boring moth was one of the only insects ever found in our surveys on knotweed roots, which is surprising since the roots must represent a large potential food source. The moth was able to chew its way out of plastic food containers, so it was with some relief that we found it feeding on the roots of a completely unrelated plant and were able to reject it.

Ostrinia moth(s)

There are a number of stem mining moths in Japanese knotweed in Japan and one of them, *Ostrinia lattipenis,* may well be specific to knotweed. The others, some so common as to be used as fishing bait, are not adequately specialist. Our North American collaborators are currently investigating this species.

Puccinia rust

We were very excited to find this rust fungus early in the project. Rust fungi have a very good record in the biological control of weeds. More than two and a half years of life-cycle studies and host range testing revealed that the rust could attack *Rumex longifolius,* a UK native, and it was rejected. There is a however, a possibility that rust strains exist that may be adequately specific.



Aecidium rust

This surprisingly damaging *Aecidium* species was found early in the knotweed growing season but from the beginning, we suspected that the later stages of the rust had another host. In year two we found it preparing to over-winter on a large grass stand. Therefore counting itself out.

This small selection of the many agents rejected along the way, shows in part how thorough the selection process is for a modern biological control agent. Only very few natural enemies have evolved such an intimate relationship with their host as to have sacrificed the ability to feed on other plant species. These are the specialist agents that biological control scientists seek.

Compiling a test plant list for the biological control of Japanese knotweed

What is a test plant list?

Besides the identification of potential biological control agents, the compilation of a test plant list is arguably the second most important component of any biological control programme. Any potential non-target effects must be critically evaluated prior to release to ensure the safety of native, economically important and ornamental plant species. The species on the test plant list are used to scientifically evaluate the specificity of the biological control agents, ensuring they only feed or infect the target weed.

Choosing which plants to test

All plant species are categorised into groups depending on their relatedness to one another. Based on morphological and phylogenetic similarities, the most closely related species form a group called the genus. Because of their similarities, members of a genus are much more likely to react in a similar way. This is the basic premise behind the scientific method used to draw up the test plant list for the proposed agents for Japanese knotweed.

Known as the "centrifugal phylogenetic method", this model for test plant selection has been used to great effect for over 30 years. It focuses on the most closely related species to the target weed in the area of introduction, gradually expanding the number of species to include more distantly related plants until specificity is established. Within a framework of risk assessment, further plants considered to be at potential risk can also be added to the test list. This allows for plants which have a similar habitat or are ecologically similar to the target weed be tested against to ensure they won't be affected.

Finally, plant species which are known to be attacked by related organisms to the proposed biological control agent, either in the plants native or introduced range, are also be included. This approach continues to serve as the basis of current host-range testing protocols as recognised by the IPPC Code of Conduct for the Import and Release of Exotic Biological Control Agents (ISPM No.3).

The test plant list for Japanese knotweed

Japanese knotweed belongs to the genus *Fallopia.* All plants of the genus native to the UK, and those which occur in the native range and have been introduced to the UK as ornamentals, were included on the list. We then move onto the "family". This is made up of a number of genera which each contain common ancestors. Although these plants may differ in form due to their evolutionary diversion, they still maintain common attributes. The genus *Fallopia* belongs to the family Polygonaceae which contains over 1,100 species worldwide and contains some well known genera which are native to the UK including *Rumex* (Docks and Sorrels), *Polygonum* (Knotgrass) and other genera not native to the UK but of economic importance including *Rheum* (Rhubarb) and *Fagopyrum* (Buckwheat). Where species were present in the UK from the genera of Polygonaceae, either in the form of native or introduced species, representatives were selected from each group.

Representative species were also selected from all major families of the order Cayophyllales (carnations, amaranths etc), as were plants species which have a similar biochemical and morphological composition to that of Japanese knotweed. Finally, 10 economically important plant species, mainly crop species, were included into the test plant list, as even though it is highly unlikely that these species would ever be affected, it is important to ensure their absolute safety given their importance.

In the UK, many of the most closely related species to Japanese knotweed are themselves invasive non-native species, such as *Fallopia sachalinensis* (Giant knotweed), *Fallopia baldschuanica* (Russian vine) and *Fallopia x bohemica*, which is a hybrid of Japanese and Giant knotweed. We only have two native species of *Fallopia*, namely *Fallopia convolvulus* and *Fallopia dumetorum.* Both bindweeds, the former is a widespread weedy species of gardens and wasteland and the later is a rather rare species which is found growing in hedgerows in central England. The test plant list included the entire native and introduced species from the genus *Fallopia* found in the UK.

In total, the test plant list for the biological control of Japanese knotweed contained 90 species and varieties including representatives from 19 plant families. This included 37 species which are native to the UK, 23 species introduced to the UK, 3 species native to mainland Europe, 13 ornamental species and 10 economically important UK species.

Sourcing and growing the test plants

The plant species in the test plant list were sourced from numerous suppliers throughout the UK, Europe and America in the form of seeds, whole plants and rhizomes (root matter). All species were grown in CABI's greenhouse facilities by plant technicians and their maintenance was by organic means only, as any chemical application may have affected the way the biological control agent behaves on the plants.

Previous biological control successes

Classical biological control is usually defined as the use of natural enemies to suppress populations of pests such as insects and weeds. When introduced to new regions or countries, pests often arrive without the suite of natural enemies which keep them in check in their native range. As a result, they often undergo periods of uncontrolled growth and expansion long before existing predators, parasitoids or diseases can adapt to them or before management strategies, including biological control, can be developed.

The principle of biological control goes back a long way, with records dating back several thousand years of farmers in China and the Yemen moving ant colonies, among citrus groves and date palm trees respectively, to control foliage feeding pests. However, it was the striking success achieved in the control of the cottony cushion scale insect, a pest of citrus fruits in California, through the introduction of the Vedalia lady beetle from Australia in the late 19th Century which marked the beginning of modern classical biological control (importing and releasing an organism outside its natural range to control a pest species). Intensive activity in this field continued into the 20th Century.

Since then, there have been many successes world-wide in the biological control of terrestrial and aquatic weeds as well as arthropods, often attributed to the introduction of a single agent. Below are some examples:

Insect vs. Insect

Jacques Regad, Département de la Santé des Forêts, Bugwood.org

Biocontrol of spruce bark beetle (*Dendroctonus micans*) in Great Britain

Of northern Eurasian origin, the great European spruce bark beetle was first discovered in Britain in 1982. The adult beetles bore into spruce bark and the females lay eggs in characteristically shaped galleries in the cambium layer beneath the bark. Large numbers of these beetles can weaken or even kill the tree. In order to help overcome the natural defences of the tree, the adult males release an aggregation pheromone attracting both males and females to the site and building up the infestation further. Spruce is our most important commercial tree species and not controlling this pest would have posed a major economic problem for the UK's forestry industry, as well as threatening the environment, so a long term management strategy was a high priority.

Fortunately help was available in the form of another exotic beetle, a predator, *Rhizophagus grandis*. *The spruce bark beetle* has no natural enemies in the UK, so the highly specific *R. grandis* had to be sourced from Belgium, reared and released for this strategy. It has now established itself in Britain and is successfully holding back the bark beetle populations.

Biocontrol of the scale insect (*Orthezia insignis*) on St Helena

The small South Atlantic British Dependency island of St. Helena has a unique and internationally significant flora, which in turn provide habitats for rare and unusual species. Unfortunately, invasive species are causing a problem. Designated as the island's national tree, the St Helena gumwood (*Commidendrum robustum*) is endangered and can only be found on this island. Once covering a third of the island, felling for fuel and timber has taken its toll and only 1,000 trees remained. Then, in 1991 a sap sucking scale insect threatened to devastate the remaining population. Fortunately, Hawaii and several African countries previously affected by the same insect, had already had success controlling populations through the introduction of a specialist predatory ladybird (*Hyperaspis pantherina*) and it was well researched. Subsequently, the St Helena Government gave permission to release the ladybird beetles in 1993 and there have been no further scale problems reported since 1995. This is a great example of a biological programme initiated solely for conservation of indigenous biodiversity and its success has saved the rare endemic gumwoods of St Helena from extinction.

Insect vs. Weed

Biocontrol of red floating fern (*Azolla filiculoides*) in South Africa and the UK

Native to South America, this small, aquatic, free floating fern became a serious weed in South Africa. It reproduces rapidly into thick mats and had a severe impact on aquatic biodiversity and water utilisation. *Stenopelmus rufinasus*, a highly specific frond feeding weevil (beetle) from Florida was released against *Azolla* in 1997 and caused extinction of the weed at 81% of original sites within seven months. Despite local extinctions of its host plant, the weevil persisted by moving between infestations and as a result, *A. filiculoides* no longer poses a threat to aquatic ecosystems in South Africa. *Azolla,* deliberately introduced into Europe and mainland Britain in the late 1800's as an ornamental pond plant, is now well established in the UK where it invades ponds canals, lakes, dykes and other slow moving fresh water.

Mechanical control is labour intensive and impractical, whilst chemical management options are limited around water bodies. The *Azolla* weevil had already proven itself to be an excellent biological control agent in South Africa and by chance, was introduced accidentally from the Americas with the weed. Now considered to be ordinarily resident, the weevil has proved it can be just as effective at controlling its host in the UK but is hampered by a low tolerance to the cold winter months, often recovering too slowly to catch up with the proliferating *Azolla*. By maintaining cultures in glasshouses all year round, CABI scientists are able to provide a 'seed population', which will multiply on its own until it reaches a size at which control is exerted. Control can thus be achieved in relatively short time and the weevils offer a safe and effective, biological control option for *A. filiculoides*.

Biocontrol of Purple Loosestrife (*Lythrum salicaria*) in the United States

Purple loosestrife was introduced to the United States and Canada from Europe as an ornamental plant. In its native range, it is rarely dominant and can be found on the margins of lakes and swamps. In the introduced range however, it has become invasive in natural areas, forming large stands and degrading many prime wetlands. Now found in 48 states, it reduces the biomass of nearly 50 native plant species, endangers rare marsh wildlife and restricts access to open water. Again, the costs associated with purple loosestrife are large – in the late 1980s around $45.9 million was spent each year to control this weed across 19 US states.

A biocontrol programmeme began in 1987, and CABI's scientists evaluated more than 100 insect species associated with purple loosestrife in Europe. Six proved to be safe for release in North America. Of these, two leaf-eating beetles, *Galerucella calmariensis and G. pusilla,* have proved particularly effective. As a result of this work, this aggressive invader is now being successfully controlled in the western and midwestern USA – 95% of purple loosestrife biomass is destroyed within two to five years of release – which allows native wetland plants to permanently replace stands of the weed.

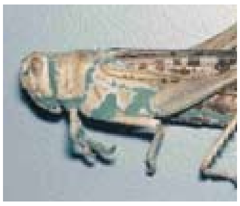
Fungus Vs. Weed

Biocontrol of rubber vine (*Cryptostegia grandiflora*) in Australia

The rubber vine weed was introduced to Australia from Madagascar in the 19th century as an ornamental garden plant and as a source of latex. An aggressive climber capable of smothering trees up to 40m high, it was described as the single biggest threat to natural ecosystems in tropical Australia and had a huge impact on pastoral areas. By the late 1980s, the rubber vine infestations were so vast (covering 40,000km^2), across often remote areas, that wide-scale chemical control was impractical, uneconomic and environmentally undesirable. As the weed advanced towards the prestigious national parks of the Northern Territory, urgent calls were made for its widespread control.

Exploratory surveys by CABI scientists in Western Madagascar revealed a rust fungus, *Maravalia cryptostegiae*, to be a highly promising biological control agent. After extensive trials to assess its safety, aerial releases were made in Australia in 1995 and it is proving to be one of the most successful biological control programmes ever carried out against an alien invasive weed. Originally predicted to take 10 years, the rust delighted farming communities by bringing the weed under control earlier than expected, defoliating and killing the weed and allowing regeneration of native forests, providing a net value of AU$232.5 million – a figure which grows year on year.

Fungus vs. Insect



LUBILOSA (LUtte BIologique contre les LOcustes et les SAuteriaux – Biological Control of Locusts and Grasshoppers)

Locusts and grasshoppers often cause extensive and serious damage to crops in many parts of Africa and Asia. Well known for invading crop areas in their millions, locusts leave a trail of devastated fields and plantations behind them. Grasshoppers are also a chronic problem as they cause serious yield losses in most years. Chemical insecticides are widely-used throughout the world to control pests and diseases on agricultural land; however they adversely affect human health and can cause environmental problems.

CABI scientists led a project known as LUBILOSA which developed an environmentally sustainable alternative to chemical insecticides to control locusts. The team studied over 160 strains of fungi and other locust pathogens. The final product is a mycopesticide known as Green Muscle™, which is based on naturally occurring insect pathogenic fungus *Metarhizium anisopliae* var. *acridum*. This occurs naturally throughout Africa so the product can easily be mass produced.

The product is applied to fields using conventional spraying methods and infects the locusts and grasshoppers present. Studies show that the mycopesticide gives direct environmental benefits and is a sustainable non-chemical control measure for locusts and grasshoppers. It is now distributed and used throughout Africa.

FAQs

What are invasive non-native species?

Invasive non-native species are those plants and animals introduced outside its natural range through the direct or indirect action of man and which damage our environment, the economy, our health or the way we live.

Invasive non-native species are estimated to cost the British economy at least £2billion a year. They are one of the greatest threats to wildlife worldwide, and their impacts can be far reaching. They adversely impact on native wildlife by predation, competition and spread of disease. They also threaten economic interests such as agriculture, forestry, fisheries and development.

Invasive alien species are often introduced either as pets or garden plants or they arrive as stowaways within imports of compost, timber, ballast water and other materials. For more information, see www.nonnativespecies.org.

Why has Japanese knotweed become such a problem?

The balance of nature was disrupted by human intervention when this plant was introduced. Without any of the checks and balances inherent in its native range, knotweed will continue to benefit from an unfair advantage over our native flora. Fly tipping and poor control efforts have exacerbated the problem.

Why use natural control methods?

It is in all our interests that invasive non-native species are not released into the wild, and the priority in the Invasive Non-Native Species Framework Strategy for Great Britain is to educate the public about the risk of introducing these species. However where an invasive non-native species is found we need to consider whether to control these species, and the possible tools to do so. Invasive non-natives usually have an advantage over native species as they have often left their natural enemies behind – one tool is the use of natural predators that target only the invasive species.

Why can't we just leave things as they are?

Japanese knotweed costs the British economy many thousands of pounds each year to manage and is only likely to get worse if left unchecked. It damages buildings, delays developments, and forces out native plants.

If left unchecked, it will continue to spread rapidly. Even where there is a concerted effort to control the weed, it is still spreading.

Is there a danger of releasing another alien species that will become invasive?

The proposed control agents have been trialled on 90 plants focusing on closely related native species as well as important crops and ornamental species to ensure they do not attack other plants. They will only be released after vigorous testing, peer review and public consultation.

Whilst the natural control agent is not native to the UK, it is "native" to knotweed. Only co-evolved natural enemies are considered as control agents and some of these will have sacrificed their ability to feed on other species in order to specialise on the target weed. By applying internationally-accepted safety testing procedures to a selected agent, it is possible to demonstrate that the risk to UK native biodiversity or crops is negligible and the organism will not be harmful.

Is this anything like GM?

No. Genetic modification involves human intervention to provide an organism with certain genes that code for desirable traits. In the case of natural control "Mother Nature" has done the modifying for us through the process of evolution. Natural control aims to allow a natural balance to be restored by the re-association of an invasive plant and its natural control agent.

How can it be that these natural enemies only attack one plant?

Most insects and pathogens are restricted in what they are able to feed on and some are monophagous, meaning they will only attack one species of plant. This is not as surprising as it seems. Many endangered insects are under threat because their only host plant or its habitat has become rare and they are unable to feed on anything else. Of course some insects and pathogens will eat all kinds of plants but these are rejected as potential natural control agents during the safety testing regime.

How can one tiny beetle or fungus do the job?

One tiny organism on its own will not have much effect but once it has reproduced for a few seasons with a very large food supply, the population can grow to become a force to be reckoned with. Although the population of a species does not normally expand very rapidly, this is much more likely to occur in the case of a natural control agent, since they too have lost their natural enemies. Insects or fungi will continually debilitate the plant and prevent it from competing as successfully. There are many examples of specialist agricultural pests that have devastated single crops. Safety testing will ensure that it is the knotweed that is affected in this case.

What will it eat when it has eaten all the weeds?

A natural control agent does not do itself any favours if it completely eradicates its only host plant; it will be faced with certain death given that it cannot feed on anything else. Fluctuations in the pest and predator populations are normally observed until equilibrium is reached. This is when the weed population is pushed below a necessary threshold level. It will stay like this indefinitely, providing constant and perpetual control without any further cost. Because the selected natural enemy will be specific to knotweed it will not be able to move onto and affect another plant.

What about the cane toad?

The cane toad, *Bufo marinus*, was introduced to Australia by the sugar cane industry in 1935 in an ill-judged attempt to control pest beetles. This was done against the recommendations of scientists at the time. Thousands of toads were released without any host specificity testing and not only failed to control the beetle but turned their carnivorous attention to anything that moved and was small enough to be swallowed. They went on to become a significant problem themselves. Although carried out in the name of natural/biological control, today's practitioners consider this to have been an act of madness and the use of such *polyphagous* (generalist eaters) vertebrate agents would never be attempted, or indeed allowed, today.

What about the harlequin ladybird?

The harlequin ladybird (*Harmonia axyridis*) was introduced as a biological control agent to several European countries in the 1990's (not the UK). The aim of the releases was to provide temporary control of aphids in greenhouses and on orchards and other crops outdoors. However, the ladybird has since managed to spread into the wild across more than 15 European countries including the UK. The harlequin ladybird is a voracious predator and is out-competing native ladybird species through direct predation and competition for food.

Although this is not an example of classical biological control (as unlike the proposed release of the psyllid, the harlequin ladybird was never released for permanent establishment), this is an example of the need for appropriate regulation of the introduction of biological control agents. CABI supports international initiatives to ensure that biological control is carried out safely, most recently as a partner in the EU Policy Support Action REBECA (Regulation of Biological Control Agents) to develop more balanced procedure for risk assessment and regulation of all types of biological control agents in Europe.

Do natural control methods work?

There have been many notable successes in the natural control of weeds, although some of course work better than others. The general consensus is that any contribution to a reduction in current control costs and efforts that outweighs the cost of the programme should be considered a success. A recent review of natural control programmes revealed a mean cost:benefit ratio in excess of 1:200 and though there was considerable variation, all were found to be positive. A good example of this is the use of the weevil *Cyrtobagous salviniae* to control Salvinia weed in Sri Lanka. This plant was introduced into the country during the Second World War to prevent enemy aircraft from identifying waterways. It did the job so well that almost all waterbodies in the country were affected. The weevil was released in 1986 and within 4 years it had destroyed around 80% of weed infestations. Since its discovery *Cyrtobagous* has been a successful control agent against this weed in more than 10 tropical countries around the world and is still working today.

Is natural control safe?

There have been over 1,000 releases of natural control agents around the world. In all, 350 different agents have been released against 133 different target weeds. CABI is a world expert in natural control and played a vital role in the development of an International Code of Conduct on the use of natural control. CABI also has a very good international track record of researching and releasing natural control agents. In countries like the US, Canada, Australia and New Zealand natural control is often viewed as the first line of defence when a new and problematic invasive species is identified.

In contrast, Europe is yet to sanction the release of a natural control agent to control an invasive weed. This is partly due to the differing scale of the problem of invasive species in Europe in the past, however the problem is increasing, and at an alarming rate.

What if it goes wrong?

Of the 1,000 worldwide releases, only eight produced non-target effects and all bar one was predicted by scientists prior to release. A famous case where a weevil ended up attacking native thistles in North America, as well as the target thistles, is a prime example. However, the predicted damage to, in some cases rare species, was deemed to be an acceptable risk at the time, given the scale of the problem. However, given the same data and situation, it is highly unlikely that today's decision makers would authorise such a release.

The care taken prior to releasing a natural control agent is in strict contrast to the wholesale importation of alien species, either as pets or garden plants and their pests, or as stowaways within many commodities.

Will releasing a natural control agent completely eradicate Japanese knotweed in the UK?

No. Eradication is not the normal outcome of natural control since it is not in the agent's interest to eradicate its only food source. Long term control, below an economic or environmental threshold, should be anticipated.

How will releasing a natural control agent affect other organisms?

Any agent considered safe for release will be highly specific to Japanese knotweed and the only impacts on other plant species should actually be beneficial. When a knotweed infestation is reduced, native plants can re-colonise areas and biodiversity should recover. However, some predators and/or parasites may take a liking to a new potential food source/host and either increase in number or desert their normal hosts. Such secondary or tertiary impacts are extremely difficult to predict from quarantine studies. However, as there won't be any existing specialist natural enemies in their new environment that will feed on the insects, the risk of this should be reduced.

Has natural control been used before in the UK or around the world?

More than 1,000 release of natural control agents have taken place worldwide. In countries like US, Canada, Australia and New Zealand natural control is often viewed as the first line of defence when a new and problematic invasive species is identified.

There have been no official releases of exotic natural enemies against weeds in the UK or Europe. However, there have been hundreds of instances of the use of insects against insects in Europe. A good example of this is the use of specialist predatory beetles against the pest spruce bark beetle in the UK which was a remarkable if under-reported success.

Will anyone make any money out of a release?

No. Natural control projects are activities for the "public good" and there is no money to be made. CABI is a not-for-profit organisation and received the funding required for the research phase of the programme from the consortium of sponsors.

How long will it take before a real impact is achieved?

Experience from around the world has shown that natural/biological control for most species takes between five and ten years from the initial releases to the time effective control is achieved. Whilst more traditional management techniques such as mechanical and chemical control seem to offer more immediate control, one of the most important advantages of natural control is the long-term management it provides. In the early days chemicals will be used alongside the natural control agents in order to achieve a good level of control. However, the prolonged impact of the agent means that natural control will be increasingly effective and the plant will continue to be controlled for many years after the initial release.

Can I sit back and wait or should I continue to try to control knotweed?

Anyone with knotweed on their land should take advice on the best control measures with reference to the Environment Agency's code of practice and continue to implement control measures as appropriate. Any delay will only allow the plant to establish more rhizome (root system) and make it harder to control, whichever method is applied.

What is the current law governing Japanese knotweed?

Due to its vigorous nature and the damage it causes, Japanese knotweed is one of only two terrestrial plants listed by the UK Wildlife and Countryside Act as illegal to cause it to grow in the wild. Fore more information see: www.jncc.gov.uk/page-1377.

How long before any agent can be released?

Applications for release of the psyllid have recently been made through the two regulatory processes: for the release of a non-native control agent; and for plant health. The licensing authority is the Food and Environmental Research Agency (Fera) and the Department for Environment, Food and Rural Affairs (Defra) holds policy responsibility and will make the final decision. However, there is no presumption to allow a release.

Fera consulted statutory advisors and an academic expert on biological control. It has also consulted the independent Advisory Committee on Releases to the Environment (ACRE). Fera is also holding a public consultation on the Pest Risk Analysis for the species as part of the regulatory process.

The earliest time at which a natural control release could be realised is spring 2010 but only if the regulatory authorities are satisfied that the potential risks outweighs the benefits and decide to licence the release of the psyllid.

Is Japanese knotweed a problem in mainland Europe?

Yes, Japanese knotweed is a major problem in many European countries. It would be relatively easy to extend the release to countries on the continent as we would just need to add their test plants to the safety testing regime and consider the use of natural enemies.

Can I keep spraying knotweed even if the insect is on it?

The agent relies on knotweed for its survival and therefore any spraying regime should be carefully integrated with the lifecycle of the agent so as not to deplete its food supply and to maximise the impact on the weed in a synergistic way. Spraying knotweed in the autumn should allow the agent to have maximum impact throughout its growing season, draining nutrients, whilst then ensuring that systemic chemicals are taken down to the rhizome just before deterioration begins.

Are you looking to use natural control on any other invasive species?

Natural control could be considered for any non-native invasive species providing that its impact is deemed sufficient for the research to be justified. In the plant world, CABI is currently working on Himalayan balsam and floating pennywort. CABI's team in Switzerland are also considering using natural control against insects such as the lily leaf-beetle and the horse chestnut leafminer.

What is the government's Invasive Non-Native Species Framework Strategy for Great Britain?

In May 2008, England, Scotland and Wales launched a co-ordinated strategy to reduce the threat to Britain's native biodiversity from invasive non-native species.

The GB Non-Native Species Secretariat is the focal point for non-native action by the English, Welsh and Scottish administrations. www.nonnativespecies.org.