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Classical biological control of *Fallopia japonica* in the United Kingdom – lessons for Europe

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Summary

The programme for the biological control of *Fallopia japonica* in the United Kingdom has provided some valuable insights into the practicalities of delivering a classical biological control programme against a weed in the European Union. In the absence of tailored legislation, the licensing process was complex but not prohibitive. It involved the production of a pest risk analysis (PRA; based on the EPPO template), an application through national legislation (the UK Wildlife and Countryside Act), the production of peer-reviewed publications, expert committee consideration, further commissioned peer review and public consultations prior to final Ministerial judgement, which was granted in March 2010. Although there is room for some streamlining in the process, this approach has proved to be effective and robust and should be applicable to similar programmes in Europe. This is important, because classical biological control has considerable potential for the management of *F. japonica* and other weed targets throughout Europe, especially those impacting habitats where chemical use is all but impossible. The lessons learned from the knotweed biocontrol programme are discussed, and current weed biocontrol activities in Europe are briefly summarised. A classical biocontrol programme needs to deliver more than just pure science, because effective communication and negotiations in the public and political arena can provide more challenges than the traditional scientific ones.

Keywords: biocontrol, Japanese knotweed, *Aphalara itadori*, *Reynoutria japonica*, psyllid, regulation.

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Introduction

It has been estimated that up to a third of the flora of some European countries is now composed of species of non-European origin, and there is little doubt that invasive non-native species can cause significant environmental and economic damage. Such impacts are likely to increase with expanding global trade, the relaxing of EU borders and the compounding effect of climatic change (Burgiel & Muir, 2010). Under article 8h of the Convention on Biological Diversity, signatories are required to 'prevent the introduction of, eradicate, or control those alien species which threaten biodiversity'. Countries quite rightly concentrate on the first two steps, as this gives the biggest potential return on investment. However, they often fail to address the third action of mitigation. This is often the case when an invasive species has spread past the limits of early eradication and is then considered beyond control by European nations with little or no experience of classical biological control. As a weed management tool, classical biological control involves the intentional introduction of highly specific coevolved natural enemies from the area of origin of the target weed, for its permanent

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control. This tool has been extensively reviewed for success (Cruttwell McFadyen, 1998) and cost effectiveness (De Lang & Van Wilgen, 2010). It has its origins more than a century ago, yet until 2010, there had been no officially sanctioned releases of exotic classical biological control agents against weeds in any EU member country. The European Union is developing a strategy on invasive alien species. Based on present scientific knowledge, we strongly advocate the inclusion of biological control as a recommended management tool (Wittenberg & Cock, 2001) used under the guidance of ISPM 3 (IPPC, 2005). The reasons for the relative lack of awareness of classical biological control of weeds in Europe are dealt with by Sheppard *et al.* (2006) and include lack of previous experience, unclear responsibilities, poor funding and vague or indeed absent legislation (Bale, 2011). The authors made recommendations for improvement, and many of these were taken up in the case of the recent biocontrol programme against *Fallopia japonica* (Houtt.) Ronse Decr. (Japanese knotweed) for Great Britain and will be relevant to proposed work on the biocontrol of the allergenic weed *Ambrosia artemisiifolia* L. (Gerber *et al.*, 2011).

Fallopia japonica biocontrol

Fallopia japonica is a herbaceous perennial plant that is native to Japan and has become highly invasive in most European countries, most states in the USA and most of Canada. Associated impacts include an ability to disrupt infrastructure and transportation networks, owing to vigorous growth rates and a rhizome system which can penetrate hard structures including asphalt, drainage and even foundations. There are also negative impacts on biodiversity (Maerz *et al.*, 2005; Gerber *et al.*, 2008), and an economic impact which in Great Britain was estimated to be £165.6 million per year (Williams *et al.*, 2010). These characteristics, coupled with the fact that it is believed to be clonal in much of its invasive range, make *F. japonica* an excellent target for biological control (Shaw, 2003).

Research, which began in 2000 and ran to 2007, revealed that *F. japonica* and its close relatives were host to 186 species of arthropod and more than 40 species of fungi, in the main islands of Japan. After 3 years of safety-testing 90 plant species, the vast majority of the recorded natural enemies were eliminated on the grounds of safety. The most promising potential agent was found to be the psyllid *Aphalara itadori* Shinjii [Hemiptera: Psyllidae], with a high level of specificity and likely efficacy. The biocontrol programme for *F. japonica* described below provided some valuable lessons which could be of benefit to any European Member State wishing to implement similar research and release programmes.

Pick the right target

Prioritisation is still required even after determining that an invasive non-native species has a depauperate collection of natural enemies and a wide distribution with significant impacts on biodiversity and/or the economy and is difficult to control. There have been numerous attempts to develop scoring systems to aid target selection (Peschken & McClay, 1992). These initially focussed on the susceptibility of the plant to the technique, rather than the need for control and any potential conflicts of interest (Stanley & Fowler, 2004) that have been incorporated in later systems, e.g. Paynter *et al.* (2009). Public perception, political will and economics play perhaps the greatest part at the project development and funding stage, but conflicts of interest can ultimately prevent releases, potentially in the final stages of the control programme, so it is important to address these early on.

A recent foray into weed biocontrol in Europe, with the exception of limited work on *Cirsium arvense* (L.) Scop. in the 1970s (Baker *et al.*, 1972), was the case of bracken *Pteridium aquilinum* (L.) Kuhn conducted in the United Kingdom. This research identified two specialist moths native to South Africa, *Conservula cinisigna* Joannis and *Panotima* sp. nr. *angularis,* for which host range testing was completed against 71 and 54 plant species respectively (Lawton *et al.*, 1988; Fowler, 1993) and which indicated that they were host specific. Nonetheless, conflicts of interest such as bracken being considered a native species and it having become a substitute for copse-like habitat favoured by important native invertebrate species, such as the high brown fritillary *Argynnis adippe* Den. & Schiff., precluded any release from being made. An interesting recent development is the request by the European Food Safety Committee for the EU standing committee on pesticide registration to not include the herbicide asulam on the Annex 1 listing of Directive 91/414/EEC. This could mean that the use of this favoured herbicide on bracken will cease from September 2012, and the biocontrol option may need to be revisited. It is quite possible that the biocontrol agents under consideration might have opened up the bracken canopy to provide more of the copse-like habitat that the species require, but this remains untested. No significant conflicts of interest exist for *F. japonica*.

Use plant health legislation

Licensing for classical biological control agents could be carried out effectively under plant health legislation (EC

Directive 2000/29/EC). This can be advised by an appropriate risk analysis, and in the case of the psyllid, the UK Government used a slightly modified version of the European and Mediterranean Plant Protection Organisation Pest Risk Assessment (PRA) template, as available in 2008. Initially, this seems an odd tool to use, as the subject needs to be considered a 'beneficial pest', and around half of the questions are not directly relevant to the intentional introduction of a biocontrol agent. However, it proved to be relatively straightforward and has the benefit of being recognised by members of the Standing Committee on Plant Health, who were kept informed of the UK application for release. It is worth noting that the publication of the host specificity data in a peer-reviewed journal (Shaw *et al.*, 2009) certainly helped with the completion of the PRA and enhanced the subsequent credibility of the research in the wider scientific community.

Each European Member State will have incorporated some control of releases in its own legislation, and in the United Kingdom, it is through the 1981 Wildlife and Countryside Act. It was therefore necessary to comply with this, so a revised version of the application to release a non-native organism was used and passed to the Advisory Committee on Releases to the Environment (ACRE), who requested further information before passing a positive judgement. ACRE requested information on efficacy and possible secondary, tertiary and community-level responses, and some laboratory data were provided that showed increased leaf count, but reduced leaf area with relatively low psyllid loads. In addition, data were generated which suggested that in a choice situation, commercially available generalist predators did not prefer the psyllid over their 'normal' aphid prey. This was supported by subsequent studies by Broom (2009), who showed decreased performance of a native coccinellid fed exclusively on psyllids when compared with an aphid diet. One of the weaknesses of pre-release biocontrol research is that it is extremely difficult to predict efficacy or apparent competition in the field, owing to the constraint of working in quarantine facilities. Nonetheless, ACRE was satisfied that adequate information had been provided, and the dossiers were then reviewed by three independent experts and the Government's Chief Scientific Advisor, before being subject to a 3 month public consultation.

At the end of the process, the final authorisation was granted by the Secretary of State after appropriate ministerial consideration. In effect, the PRA was used to liberate the psyllid from the plant health quarantine license it was being held under, and the Wildlife and Countryside Act application was used to permit the release into the wild. These licenses had to be granted simultaneously, as one without the other would still prevent legal release. It took a considerable amount of time and numerous discussions with an inter-departmental government committee to determine the most appropriate path. Due care and attention was paid to the process, because it was recognised that this would set a precedent for future weed biocontrol activities in Europe. This committee was invaluable in determining the right path, and similar steering committees should be considered by other European Member States.

Select and agree a test plant list at the outset

In the United Kingdom, there was no mechanism for agreeing the list of plants to be used in a safety testing procedure. The decision was made not to adopt the recommendations for a reduced test plant list, as advocated by Briese (2005) and others. Instead, the list comprised a more comprehensive number of species and was thus more suited to public scrutiny. This meant the inclusion of distantly related but economically important test plants, which was perhaps unnecessary. It is crucial such lists are agreed at the outset, to avoid unnecessary testing and/or prolonging the research phase with late additions after the project has reached its conclusions. It is also vital to ensure that the proposed plants can be obtained and propagated for quarantine testing, because legal restrictions may prevent the collection of CITES listed species from the wild.

Prepare a monitoring plan in advance of release

Although not necessarily a requirement, it is highly advisable for any biocontrol release to have a monitoring plan in place, not only to detect any unpredicted non-target impacts on the receiving environment but also to record any beneficial impact of the biocontrol agent and indeed successful establishment. The English regulator made it a requirement of the license that a suitable scientific monitoring programme was not only agreed, but also fully funded. A 5 year, multi-site monitoring plan is now being followed which, in its early stages, included the planting out of the most closely related native species into the release sites. These species are intensely monitored as they could be expected to be those most likely to receive unwanted damage. It was also a requirement that a contingency plan be put in place for the early limited releases, which involved the retention of experienced, qualified sprayer operatives prepared to apply insecticide and follow-up herbicide treatment should any threat to native species be recorded.

We can find no evidence of any weed biocontrol release in the past being made with an associated contingency plan. In contrast to most efforts around the world, the knotweed psyllid was released at sites which were specifically selected for their isolation, thus limiting the chance of spread, and where there were no restrictions precluding the use of chemicals for emergency control. The number of individuals released was also inadvertently limited. This effectively meant that the first phase of the release programme in the United Kingdom was an extended safety test, rather than an attempt at establishment for which the strategies are very different (see Grevstad, 1999). This 'field safety test' would not be considered a normal part of a release programme, and its use is a reflection of the novelty of the release and might not be repeated in future programmes. The second phase involves larger releases across England and Wales, with four monitoring cycles per year at these and coupled control sites, recording foliar and ground dwelling arthropods, floral diversity and the response of the target weed.

Engage the public early and often with clear messages

From the outset, it is important to make clear that a biocontrol programme is fundamentally a research activity and that the final output is a dossier focussed on safety, with no commitment to release any agent. It was recognised early on that the media had a great interest in Japanese knotweed, and by association its natural enemies. Thus, the project team and steering committee agreed a communication plan and created the Japanese knotweed alliance website (http://www.cabi.org/japaneseknotweedalliance/), which at the time of writing was ranked number 7 of over 1.5 million results returned by Google when searching for 'Japanese knotweed'. The site includes 38 frequently asked questions, including the most commonly asked 'what will the agent eat once it has consumed all the target weed?', closely followed by 'what about the cane toad?' and 'has it been genetically modified?' By the end of the research in 2008, at least 40 oral presentations had been made at scientific and public meetings, and considerable media interest had been generated, resulting in more than 50 newspaper, television or radio articles.

It is essential to make it clear what successful classical biocontrol can deliver and, more importantly, what it definitely cannot, i.e. control vs. eradication. It is impossible to control what journalists choose to include or assume in their articles, but some welcome a researcher's offer to fact-check early drafts that can prevent misrepresentation. If expectations are raised too far, land managers may assume that biocontrol offers a quick solution and may be tempted to abandon current control efforts. Care must be taken to refer to biocontrol as a component of a long-term integrated control measure, as well as addressing people's natural fear after unrelated disasters, such as the cane toad in Australia (Tanner & Shaw, 2008).

What next for Europe?

The best cost/benefit ratios can always be delivered by projects that have 'off-the-shelf agents', i.e. those that have already been subjected to biocontrol studies and host range testing elsewhere. An example is the use of the previously utilised weevil *Cyrtobagous salviniaea* Calder & Sands against *Salvinia molesta* D.S. Mitchell in Sri Lanka that delivered a cost/benefit ratio as high as 1:1673 (Doeleman, 1989). Other examples include *Ambrosia artemisiifolia* L. (Gerber *et al*., 2011), *Azolla filliculoides* Lam. (McConnachie *et al*., 2003), *Buddleja davidii* Franchet and *Acacia longifolia* (Andrews) Willd.

After a very long delay, weed biocontrol in Europe appears to have started in earnest and current activities are summarised in Table 1. The list is clearly not based solely on the recommendations of Sheppard *et al*. (2006), but is more a reflection of researchers' personal interests and funding opportunities at the time. It does, however, provide the opportunity for other nations to contribute to, steer and ultimately benefit from the current research for relatively little cost. This was the approach taken by the USA and Canada to the *F. japonica* project, to which they have been contributing funding and test plants from the outset and should soon be submitting a petition for release of the psyllid.

The fastest and easiest way for the rest of Europe to benefit from classical weed biocontrol would be to consider the suitability of the psyllid for *F. japonica* control, because it is the only agent licensed in an EU Member State so far. The first steps could include assessing the susceptibility to the psyllid of the various varieties of *F. japonica* in interested countries, as it is believed that variation in parts of Europe is much higher than in the United Kingdom (Krebs *et al*., 2010). It is also likely that other European countries may wish to add plants to the safety testing regime that were not tested for the UK release, such as *Polygonum alpinum* All. and *Koenigia icelandica* L.

Conclusions

The classical biocontrol programme against *F. japonica* in the United Kingdom has been the first to test the licensing system in a European country, and despite a few problems, a path through regulations that were not designed with classical biological control in mind has

Table 1 Summary of current classical weed biocontrol activity in Europe

Target weed	Country/area of origin	Prioritised agent	Status	Research Team	Country of operation
Fallopia japonica (Houtt.) Ronse Decr.	Japan	*Aphalara itadori* Shinji	The psyllid licensed and released in England	CABI	United Kingdom
Acacia longifolia (Andrews) Willd.	Australia	*Trichilogaster acaciaelongifoliaea* Froggatt	Laboratory and field safety testing complete (Marchante *et al.*, 2011)	Centre for Studies of Natural Resources, Environment and Society	Portugal
Impatiens glandulifera Royle	India, Pakistan and Nepal	*Puccinia* cf. *komarovii*	*Puccinia* cf. *komarovii* selected and promising host range testing so far	CABI	United Kingdom
Lagarosiphon major L.	South Africa	*Hydrellia lagarosiphon* Deeming, *Bagous* spp.	Natural enemy surveys complete (Baars *et al.*, 2010) *Hydrellia lagarosiphon* looks promising	University College, Dublin	Ireland
Hydrocotyle ranunculoides L. f.	Argentina and Brazil	*Listronotus elongatus* Hustache, *Hydrellia* sp. (Ephydridae) and *Eugaurax* sp. (Chloropidae)	Weevil has promising host range results. Ephydrid and Chloropid flies not tested	CABI	United Kingdom
Crassula helmsii (Kirk)	Australia and Tasmania	*Steriphus* sp. indet. *Bagous* sp.	Weevil imported into quarantine	CABI	United Kingdom
Azolla filiculoides Lam.	Through the Americas	*Stenopelmus rufinasus* Gyllenhal	Weevil (classed as ordinarily resident in United Kingdom) being redistributed	CABI	United Kingdom
Solanum elaeagnifolium Cav.	South, Central and North America	Research ongoing	Exact area of origin being determined prior to natural enemy search. Some off-the-shelf agents exist	USDA European Biocontrol Laboratory/Benaki Phytopathological Institute	France, Greece
Ambrosia artemisiifolia L.	North America and Canada	Research ongoing	COST action in preparation and biocontrol is the major component. Good potential with known agents (Gerber *et al.*, 2011)	Large consortium	Europe-wide

been demonstrated. The experience gained shows that a classical biocontrol programme needs to deliver more than just pure science, because engaging in effective communication and negotiations in the public and political arena can provide more varied challenges than the traditional scientific ones. It should perhaps include not only the traditional scientific personnel, such as entomologists, plant pathologists, weed scientists, ecologists and taxonomists, but a public relations team too. It is likely that the requirements of the EU Sustainable Use Directive aimed at reducing our reliance on chemicals, the increased awareness of the impacts of invasive weeds as well as the demands of the EU Water Framework Directive will make this pioneering project especially useful to all EU Member States wishing to implement sustainable, low-cost solutions to apparently uncontrollable invasive weeds.

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References

Baars JR, Coetzee JA, Martin G, Hill MP & Caffrey JM (2010) Natural enemies from South Africa for biological control of *Lagarosiphon major* (Ridl.) Moss ex Wager (Hydrocharitaceae) in Europe. *Hydrobiologia* **1966,** 149–158.

Baker CRB, Blackman RL & Claridge MF (1972) Studies on *Haltica carduorum* Guerin (Coleoptera: Chrysomelidae) an alien beetle released in Britain as a contribution to the biological control of creeping thistle, *Cirsium arvense* (L.) Scop. *Journal of Applied Ecology* **9,** 819–830.

Bale J (2011) Harmonization of regulations for invertebrate biocontrol agents in Europe: progress, problems and solutions. *Journal of Applied Entomology*. (early online DOI: 10.1111/j.1439-0418.2011.01611.x).

Briese DT (2005) Translating host-specificity test results into the real world: The need to harmonize the yin and yang of current testing procedures. *Biological Control* **35,** 208–214.

Broom JW (2009) *Secondary Competition and Oviposition Studies of the Psyllid* Aphalara itadori*, a Novel Biological Control Agent*. Unpublished MSc Thesis, Imperial College, Silwood Park, Ascot UK.

Burgiel SW & Muir AA (2010) *Invasive Species, Climate Change and Ecosystem-Based Adaptation: Addressing Multiple Drivers of Global Change*. Global Invasive Species Programme (GISP), Washington, DC, US, and Nairobi, Kenya.

Cruttwell McFadyen RE (1998) Biological control of weeds. *Annual Review of Entomology* **43,** 369–393.

De Lang WJ & Van Wilgen BW (2010) An economic assessment of the contribution of biological control to the management of invasive alien plants and to the protection of ecosystem services in South Africa. *Biological Invasions* **12,** 4113–4114.

Doeleman JA (1989) Biological control of *Salvinia molesta* in Sri Lanka: an assessment of costs and benefits. ACIAR Technical Report TR012.

Fowler SV (1993) The potential control of bracken in the UK using introduced herbivorous insects. *Pesticide Science* **37,** 393–397.

Gerber E, Krebs C, Murrell C, Moretti M, Rocklin R & Schaffner U (2008) Exotic invasive knotweeds (*Fallopia* spp.) negatively affect native plant and invertebrate assemblages in European riparian habitats. *Biological Conservation* **141,** 646–654.

Gerber E, Schaffner U, Gassmann A, Hinz HL, Seier M & Müller-Schärer H (2011) Prospects for biological control of *Ambrosia artemisiifolia* in Europe: learning from the past. *Weed Research*, doi: 10.1111/j.1365-3180.2011.00879.x

Grevstad FS (1999) Factors influencing the chance of population establishment: Implications for release strategies in biocontrol. *Ecological Applications* **9,** 1439–1447.

IPPC (2005) *Guidelines for the Export, Shipment, Import and Release of Biological Control Agents and Organisms Claimed to be Beneficial*. FAO, Rome.

Krebs C, Mahy G, Matthies D, Schaffner U, Tiébré MS & Bizoux JP (2010) Taxa distribution and RAPD markers indicate different origin and regional differentiation of hybrids in the invasive *Fallopia* complex in central-western Europe. *Plant Biology* **12,** 215–223.

Lawton JH, Rashbrook VK & Compton SG (1988) Biocontrol of British bracken: the potential of two moths from southern Africa. *Annals of Applied Biology* **112,** 479–490.

Maerz JC, Blossey B & Nuzzo V (2005) Green frogs show reduced foraging success in habitats invaded by Japanese knotweed. *Biodiversity and Conservation* **14,** 2901–2912.

Marchante H, Freitas H & Hoffmann JH (2011) Assessing the suitability and safety of a well-known bud-galling wasp, *Trichilogaster acaciaelongifoliae*, for biological control of *Acacia longifolia* in Portugal. *Biological Control* **56,** 193–201.

McConnachie AJ, de Wit MP, Hill MP & Byrne MJ (2003) Economic evaluation of the successful biological control of *Azolla filiculoides* in South Africa. *Biological Control* **28,** 25–32.

Paynter Q, Hill R, Bellgard S & Dawson M (2009) *Improving Targeting of Weed Biological Control Projects in Australia*. Landcare Research Contract Report LC0809/072, Landcare Research, Auckland, New Zealand. 115 pp.

Peschken DP & McClay AS (1992) Picking the target: a revision of McClay's scoring system to determine the suitability of a weed for classical biological control. In: *Proceedings 1992 VIII International Symposium on Biological Control of Weeds* (2–7 February 1992, Lincoln University, Canterbury, New Zealand). CSIRO, Melbourne, Australia, 138–143.

Shaw RH (2003) Biological control of weeds in the UK: opportunities and challenges. In: *Plant Invasions, Ecological Threats and Management Solutions*. (eds L Child, JH Brock, G Brundu, K Prach, P Pysek, PM Wade & M Williamson), 337–354. Backhuys Publishers, the Netherlands.

Shaw RH, Bryner S & Tanner R (2009) The life history and host range of the Japanese knotweed psyllid, *Aphalara itadori* Shinji: potentially the first classical biological weed control agent for the European Union. *Biological Control* **49,** 105–113.

Sheppard AW, Shaw RH & Sforza R (2006) Top 20 environmental weeds for classical biological control in Europe: a review of opportunities, regulations and other barriers to adoption. *Weed Research* **46,** 1–25.

Stanley MC & Fowler SV (2004) Conflicts of interest associated with the biological control of weeds. In: *Proceedings 2003 XI International Symposium on Biological Control of Weeds*, CSIRO Entomology, Canberra, Australia. 322–340.

Tanner R & Shaw RH (2008) Beyond the cane toad. *Biocontrol News and Information* **29,** 49N–72N.

Williams F, Eschen R, Harris A *et al*. (2010) *The Economic Cost of Invasive Non-Native Species to Great Britain*. CABI E-UK report, 198 pp.

Wittenberg R & Cock MJW (2001) *Invasive Plant Management*. CABI, Wallingford