Impatiens glandulifera *is a large annual plant native to the Himalayas. © Zygmunt Dajdok*

The management of Himalayan balsam (*Impatiens glandulifera*)

Measures and associated costs

Scientific name(s)	*Impatiens glandulifera* Royle
Common names (in English)	Himalayan balsam
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Common names

BG	Жлезиста слабонога
HR	Žljezdasti nedirak
CZ	Netýkavka žláznatá
DA	Kæmpe-balsamin
NL	Reuzenbalsemien
EN	Himalayan balsam
ET	Verev lemmmalts
FI	Jättipalsami
FR	Balsamine de l'Himalaya
DE	Drüsiges Springkraut
EL	Βάλσαμο των Ιμαλαΐων
HU	Bíbor nebáncsvirág
IE	Lus na pléisce
IT	Balsamina ghiandolosa
LV	Puķu sprigane
LT	Bitinė sprigė
MT	–
PL	Niecierpek gruczołowaty
PT	Bálsamo-do-Himalaia
RO	Slăbănog himalaian
SK	Netýkavka žliazkatá
SL	Žlezava nedotika
ES	Bálsamo del Himalaya
SV	Jättebalsamin

Summary of the measures, emphasizing the most cost-effective options.

Himalayan balsam *Impatiens glandulifera* Royle (Balsaminaceae) is a highly invasive non-native annual species that has spread rapidly throughout Europe (Pyšek *et al*., 1995) and North America (Cockel and Tanner, 2011), since its introduction from the foothills of the Himalayas at the beginning of the 19th century. It is now the tallest annual plant species in Europe, attaining a height of up to 2.5 m (Beerling and Perrins, 1993, Tanner *et al*., 2014). Himalayan balsam is predominantly a weed of riparian habitats, though it will flourish in damp woodlands and waste grounds (Environment Agency, 2010, Tanner *et al*., 2013).

Himalayan balsam has been shown to displace native vegetation when the cover is high (Hulme and Bremner, 2006) and displace associated invertebrate populations (Tanner *et al*., 2013). In turn, a reduced cover of native vegetation can negatively impact on above ground invertebrate communities, which are reliant on native plant species (Tanner *et al*., 2013). Below-ground invertebrate populations are largely unaffected and in some cases increase (such as Collembola) beneath infested stands, due probably to increased root biomass (Tanner *et al*., 2013).

Prevention: The most appropriate measures for preventing Himalayan balsam from entering a Member State are (1) the ban on keeping, importing, selling, breeding and growing as required under Article 7 of the IAS Regulation and (2) Phytosanitary measures, for example phytosanitary inspections. Seeds are the most likely life stage to ban from sale as the species is not traded in live plant form (Tanner, pers. obs., 2017).

The only feasible method for **early detection** of Himalayan balsam is visual inspection. The species is relatively easy to identify in the field, as it is now the tallest European annual plant species with bright purple/pink flowers. Citizen-science networks could help to expand the local and regional network for identifying Himalayan balsam in the field.

Rapid eradication, following identification in the field, may be conducted using manual, mechanical and chemical options. All of the aforementioned control options are effective at controlling populations of Himalayan balsam – from small to large extents. Management should be conducted on a catchment scale, working downstream. It is, however, the habitat where the species occurs which limits the effectiveness of the control options. For example, where Himalayan balsam occurs in a riparian system, downstream management efforts may be limited. Chemical application to a population close to a riparian habitat is unlikely to be permitted, and if so only to a limited extent and any application will need to adhere to guidance and restrictions. Chemical control may be viewed negatively by stakeholders due to the nontarget damage. In addition, there will be many areas where chemical application is not allowed. In relation to chemical control, EU/national/local legislation on the use of plant protection products and biocides needs to be respected.

Management of existing populations is feasible with manual, mechanical and chemical options taking into consideration the limitations to management on rivers as detailed above. In addition to these methods, biological control has been researched and applied against this species in Great Britain. Using a host specific rust fungus (*Puccinia komarovii* var. *glanduliferae*) the biocontrol of the species looks promising. The rust was released in Great Britain in 2015 and has since survived over winter. It should be borne in mind that the release of macro-organisms as biological control agents is currently not regulated at EU level. Nevertheless national/ regional laws are to be respected. Before any release of an alien species as a biological control agent an appropriate risk assessment should be made.

Measures for preventing the species being introduced, intentionally and unintentionally.

This section assumes that the species is not currently present in a Member State, or part of a Member State's territory.

A ban on importing (pre-border measure), selling, breeding, growing, and cultivation, as required under Article 7 of the IAS Regulation, targeting intentional introduction of plants and propagules of *I. glandulifera.*

MEASURE DESCRIPTION

A significant pathway for entry or spread of Himalayan balsam (*Impatiens glandulifera*) into the EU, or between Member States, is through the purchase or exchange of seed material (Pisarczyk and Tokarska-Guzik, 2015). A ban from sale helps to regulate this pathway for the species. The species is also traded between Member States via internet suppliers.

EFFECTIVENESS OF MEASURE

If measures are not implemented by all countries, they will not be effective since the species could be planted and may spread from one country to another especially where river systems are shared by more than one country. Seeds that enter a water course from a bank side population can spread up to 10 km before germinating the next spring (IRD Duhallow LIFE Report, 2015). National measures should be combined with international measures, and international coordination of management of the species between countries is recommended.

If this measure is applied robustly throughout the region, a ban from sale is an effective measure to help prevent the entry of the plant into the region.

EFFORT REQUIRED

A commitment to public awareness is required to disseminate the message that Himalayan balsam is banned from sale and this should be backed up with detailed information highlighting the negative impacts of this and other invasive alien species. Environmental NGOs can assist in information dissemination to the public.

RESOURCES REQUIRED

A ban from sale requires resources including financial resources, staff time and the development of communication material from a number of sectors, including governmental, regulators, horticulture and horticultural suppliers, the general public, and environmental NGOs.

Communication material detailing the negative impacts of the species would be essential to educate the public and support a ban on sale. Himalayan balsam has been popular with members of the public and it has been detailed that in the past people have actively spread the species throughout the countryside in the UK (Rotherham, 2001).

It is estimated that the cost for an awareness raising campaign could be up to €10,000 per year (which would include the cost to produce and disseminate information material along with associated staff costs) for each Member State. However, sectors of society may bear some of these costs themselves.

SIDE EFFECTS

Potential side effects include a loss to the trade of Himalayan balsam. However, this is likely to be of minor impact to the trade. Most of the business in sales of Impatiens comes from the sale of just two species and their varieties, *I. walleriana* (Busy Lizzie) and *I. hawkeri* (the New Guinea hybrids) (Morgan, 2007). Lagging far behind these two species in the sheer numbers of varieties available are *I. balsamina* (the first *Impatiens* species to be cultivated as early as 200 years ago (Moran, 2007)).

The Royal Horticultural Society (RHS) (Great Britain) list some 30 species of the genus Impatiens and 5 breeds: *Impatiens glandulifera* 'Red Wine', 'Mien Ruys', 'Pallidiflora', 'Candida' and 'Sugar Loaf Peach'. Additionally, 38 varieties on its plant finder website (http://apps.rhs.org.uk/rhsplantfinder/). In addition, there are numerous suppliers of *Impatiens* seeds, though again most concentrate on the Busy Lizzie's and New Guinea hybrids.

ACCEPTABILITY TO STAKEHOLDERS

Any regulation of Himalayan balsam may be viewed negatively by some members of the public. The species has an extended flowering time compared to other European natives (Prowse and Goodridge, 2000), and coupled with

The flower shape has been compared to a policeman's helmet. © Wolfgang Rabitsch.

high rates of sugar production, this plant is favoured by beekeepers (Showler, 1989; Starý and Tkalcu, 1998). Some members of the public find the plant an attractive addition to the European flora (Rotherham, 2001).

The recent decline in populations of bees (Feltwell, 2010; Blake *et al*., 2011) has further highlighted the potential use this species may have in supporting pollinating insects (Showler, 1989). It should be noted that there are studies that highlight the negative impact of increased pollinator visitations to Himalayan balsam compared to native plants. Chittka and Schürkens (2001) suggest that the species has the potential to decrease genetic diversity in native plants as it lures pollinators away from natives. Apart from the suggested benefits to *Bombus* populations, there are no other benefits of this species to the countryside, apart, of course, to the few that consider monocultures of the plant in flower an attractive addition (Rotherham, 2001).

Public awareness campaigns may highlight the risk of the species and prevent further spread of the species from existing populations.

ADDITIONAL COST INFORMATION

Implementation cost for Member States: Implementation costs for Member States are likely to be moderate.
Member States have to monitor and ensure stakeholders are following the ban and therefore there will be some enforcement costs.

Cost of inaction: Economic figures of the impact of Himalayan balsam are high and may cost Member States up to, and over, €1-1.5 million in control costs per year (Williams *et al*., 2010). When eradication is attempted on a national scale, costs have been estimated to be in the hundreds of millions for single Member States. In the UK it is estimated that eradication could cost between €174 -350 million (Environment Agency, 2003). In Switzerland, Gelpke and Weber (2005) estimated it would cost between CHF 2,183,500 and CHF 13,812,696 (€1.2-6.7 million) to eradicate 95% of the current population of Himalayan balsam in the Canton of Zürich alone.

Cost-effectiveness of the measure: A ban from sale is a cost-effective measure in the prevention of the species to new regions.

Socio-economic aspects: Negative socio-economic impacts would include a loss for the horticultural trade of Himalayan balsam. However, this is not likely to be significant as it is only seed that are traded (Tanner, pers. comm., 2017). Positive socio-economic aspects include a reduction of the plant in natural areas, in particular areas of high conservation value.

LEVEL OF CONFIDENCE[1]

A **high level of confidence** has been given to the effectiveness of a ban from sale for Himalayan balsam. However, it should be noted that a lot of the trade for the species may be via the internet and this pathway will need monitoring and regulation.

1 See Appendix

Phytosanitary inspections, in particular related to the movement of soil.

MEASURE DESCRIPTION

Himalayan balsam has the potential to be introduced unintentionally as a contaminant. For example, CABI (2017) states: 'Transport of seed with topsoil is probable (Beerling and Perrins, 1993) but it is not clear, however, to what extent this has occurred in the introduction or spread to new areas. The transport of seed with river gravel in trains was reported in Germany (Hartmann *et al*., 1995), as well as contamination of building rubbish transported to waste disposal sites'.

The author has observed the species growing in flower beds in new housing developments in London, Great Britain. It is likely that these plants are a result of the movement of contaminated soil.

Phytosanitary inspections along with associated phytosanitary measures can act to prevent the entry of the species in some commodities into specific countries/regions.

To prevent the movement of contaminated soil with Himalayan balsam seeds between EU Member States, soil management plans, identification guides, factsheets, Codes of conduct should be referred too/developed.

EFFECTIVENESS OF MEASURE

Phytosanitary inspections can be implemented on commodities coming into the EU from outside but the risk of Himalayan balsam seeds entering as a contaminant is low. The author could not find any examples where seeds had been intercepted as a containment.

It is, however, very difficult to implement phytosanitary measures within the EU due to freedom of movement of commodities between countries.

If measures are not implemented by all countries, they will not be effective since the species could spread from one country to another. National measures should be combined with international measures, and international coordination of management of the species between countries is recommended.

EFFORT REQUIRED

A significant amount of effort would be required to train inspectors in the identification of seed material of Himalayan balsam. There may be the potential for eDNA technologies but these would need to be developed as there are no known projects currently researching this technology for the species. In addition, repeated effort would be needed to continually inspect consignments and commodities at risk.

RESOURCES REQUIRED

Resources required would include: staff time of an inspector and identification material for seed identification.

SIDE EFFECTS

Negative: Increased effort is required to assess commodities at risk (such as top soil).

Positive: Seeds of other invasive plants could be included in the measures and therefore also intercepted and destroyed.

ACCEPTABILITY TO STAKEHOLDERS

See the same section in *A ban on keeping, importing, selling, breeding and growing as required under Article 7 of the IAS Regulation*.

ADDITIONAL COST INFORMATION

Implementation cost for member States: Implementation costs for Member States is likely to be high as staff time from inspectors would be required. Member States would be required to maintain monitoring over a long period.

Cost of inaction: See section in *Prevention: A ban on keeping, importing, selling, breeding and growing as required under Article 7 of the IAS Regulation.*

Cost-effectiveness of the measure: Phytosanitary inspections are not likely to be cost effective.

Socio-economic aspects: None to detail.

LEVEL OF CONFIDENCE[1]

A **low to moderate** rating of confidence has been assigned to phytosanitary inspection mainly as it is largely an unknown to the extent on the volume of movement of seed material as a contaminant from outside of the EU.

1 See Appendix

Measures for early detection of the species and to run an effective surveillance system to detect efficiently new occurrences.

Visual detection of existing populations.

MEASURE DESCRIPTION

Visual detection of plants in the field is the only feasible early detection method for new occurrences of Himalayan balsam. It is possible to identify the species in the field with very little training.

EFFECTIVENESS OF MEASURE

The different stages of Himalayan balsam are relatively easy to identify. Readily available field guides (for example, Streeter *et al.*, 2016) can be used to identify the species. It is easiest to identify the plant when it is in flower.

Himalayan balsam is the tallest European annual, commonly attaining a height of 2 m (Beerling and Perrins, 1993) and can even reach 3 m at maturity in deciduous woodland (Andrews *et al.*, 2005). The species is an attractive plant with erect hollow stems with a reddish tinge. Leaves are arranged in whorls of 2-5, lanceolate and serrulate, flowers are a variable in colour from purple-pink and occasionally almost white (Blamey *et al.*, 2003), and are produced from June to October, long after most species have senesced.

Visual detection is commonly utilised for recording Himalayan balsam in the field by amateurs and professionals.

EFFORT REQUIRED

A significant network of stakeholders is required to monitor all potential habitats where Himalayan balsam may occur

Himalayan balsam is sometimes cultivated for its flowers. © Aleksander Niweliński.

though sites most at risk could be targeted in an initial monitoring programme, for example riparian sites.

The intensity of surveillance would be more extreme during the summer months from April to June. If identified before flowering there is the opportunity to eradicate the population.

If the plant has set seed and the pods have exploded and released the seed, the population would need to be monitored and further control measures would be needed the following season.

RESOURCES REQUIRED

Resources would involve staff time, travel costs and health and safety measures. The staff involved could come from government agencies and/or citizen-scientists. Actual costs of a monitoring programme will depend on the area surveyed.

SIDE EFFECTS

Negative: None known. Obtaining access to discrete areas of land may be problematic with the division of land ownership. If the species is not controlled at a catchment scale, seeds of remaining populations can become incorporated into the waterbody and spread to colonise new areas.

Positive: Low environmental impact and low cost to implement.

ACCEPTABILITY TO STAKEHOLDERS

The visual detection of Himalayan balsam is likely to be acceptable to stakeholders and no significant impacts are envisaged. However, it should also be noted that stakeholders may choose not to report findings to avoid associated management costs.

ADDITIONAL COST INFORMATION

Implementation cost for Member States: Implementation costs will vary considerably based on the area needed to survey. Engagement with the local environmental NGOs and utilisation of the volunteer network can further reduce costs.

Some regional training workshops could be conducted to train stakeholders in identification, management and safety aspects, it is estimated that each training workshop may cost in the region of €3,000.

Cost of inaction: See section in *Prevention: A ban on keeping, importing, selling, breeding and growing as required under Article 7 of the IAS Regulation*.

Cost-effectiveness of the measure: This measure has the potential to be very cost effective if Member States engage with local Wildlife Trusts or River Trusts and utilise their expertise. Regional funding should be made available to local NGOs to monitor all potential invasive alien plants. A proportion of the cost of two staff members (40% full time equivalent) plus consumables and travel is estimated at €60,000 per year.

Socio-economic aspects: There are no socio-economic aspects to detail for this measure.

LEVEL OF CONFIDENCE[1]

A **moderate** rating of confidence has been given as although the species is relativity easy to identify in the field, the plant can be inconspicuous until it flowers late in the season (July-September).

1 See Appendix

Measures to achieve rapid eradication after an early detection of a new occurrence.

Manual and mechanical control.

MEASURE DESCRIPTION

Mechanical and manual control can take the form of cutting using basic hand-held non-motorised utensils or motorised machinery such as mowers or strimmers. Larger agriculture machinery may be used in more open habitats.

EFFECTIVENESS OF MEASURE

Discrete populations of Himalayan balsam can be eradicated using manual and mechanical methods. IRD Duhallow LIFE Report (2015) details the effectiveness of manual control of a catchment population over a three-year period, where almost 100% of the population was eradicated.

Complications can arise when the species is being controlled on a catchment scale as all upstream populations will need to be controlled to avoid recolonisation. It is also important to note that many of our water bodies are connected and this facilitates the movement of seed over long distances.

Eradication measures should be promoted where feasible with a planned strategy to include surveillance, containment, treatment and follow-up measures to assess the success of such actions. Regional cooperation is essential to promote phytosanitary measures and information exchange in identification and management methods. Eradication may only be feasible in the initial stages of infestation, and this should be a priority.

A monitoring and surveillance programme, including early detection, should be initiated for countries most prone to risk. National Plant Protection Organisations (NPPOs) should report any findings.

EFFORT REQUIRED

There is a high level of variation of seed production between habitats and individuals (Willis and Hulme, 2004), an individual plant can produce up to 2,500 seeds and propel the seeds up to five metres from the parent plant. When Himalayan balsam forms monocultures this can equate to a seed rain of 5,000-6,000 seeds m^{-2} (Beerling and Perrins, 1993).

Manual control must be repeated over a number of seasons to ensure the seed bank is exhausted. The seed bank is relatively short-lived persisting between 18 to 24 months (Beerlings and Perrins, 1993), though seeds can remain viable for several years under artificial conditions with germination being achieved following a period of cold stratification at 4°C (Mumford, 1990). Thus, it is recommended that repeated visits to managed sites should be continued for at least three years (Tanner, pers. comm., 2017).

RESOURCES REQUIRED

IRD Duhallow LIFE Report (2015) provide specific information on the economic cost of managing Himalayan balsam where they state "Duhallow LIFE has spent to date (including personnel costs) over €200,000 on field work, control and eradication measures and associated reporting of Himalayan Balsam in the Allow River Catchment. This does not include volunteers. The entire Allow Catchment is 310.9 km^2 with the Dalua and Brogeen being the two major tributaries. Over 43 km of infested bank and drain along the Allow and Dalau rivers have been treated by hand since 2011.

It is important to note, that a constant effort is required year on year to ensure that additional populations do not establish (IRD Duhallow LIFE Report, 2015).

SIDE EFFECTS

Along riparian habitats (one of the major habitats for this species within the EU), mechanical control measures can be effective for eradicating small stands, although it can leave banks bare and without root systems to hold soil in place, thereby adding to the potential for erosion. Additional costs would be associated if restoration attempts are implemented and these could be up to €11.6 m^{2-1} (Tanner *et al*., 2008; CABI, 2017).

ACCEPTABILITY TO STAKEHOLDERS

Any control of Himalayan balsam may be viewed negatively by some members of the public as the plant is favoured by beekeepers (Showler, 1989; Starý and Tkalcu, 1998). However, manual or mechanical control of the species would be more acceptable to stakeholders compared to chemical control.

Invasive Himalayan balsam can adversely affect indigenous species by attracting pollinators at their expense. © Maciej Bonk.

ADDITIONAL COST INFORMATION

Implementation cost for Member States: Implementation costs can be relatively low and engagement with the local environmental NGOs and utilisation of the volunteer network can further reduce costs. Control costs range from €0.6 m^{2-1} (for chemical application or manual control by strimming) to €11.6 m^{2-1} when habitat restoration is included (Tanner *et al.*, 2008; CABI, 2015).

Cost of inaction: See section in *Prevention: A ban on keeping, importing, selling, breeding and growing as required under Article 7 of the IAS Regulation*.

Cost-effectiveness of the measure: Chemical control is cost-effective when controlling small populations of the species.

Socio-economic aspects: Socio-economic aspects could include a loss of revenue for beekeepers. Positive effects could include uninvaded rivers thereby enhancing cultural services and recreation activities. Himalayan balsam can restrict access to waterbodies thus impacting on recreational activities such as fishing. Angling tourism is worth €750 million to the Irish economy alone (Pisarczyk and Tokarska-Guzik, 2015).

LEVEL OF CONFIDENCE[1]

A **high** rating of confidence has been given to manual and mechanical control as these methods have been shown to be effective. It should be highlighted however that this method would need to be implemented on an annual basis and combined with visual inspection to ensure that individual plants do not establish and set seed.

1 See Appendix

Chemical control.

MEASURE DESCRIPTION

Both selective herbicides such as 2, 4-D and triclopyr, and non-selective herbicides such as glyphosate were found suitable in controlling Himalayan balsam (CABI, 2017). According to the locally applicable law, a permit may be required to use herbicides, in particular near water. It should be noted however, that chemical herbicides which were once widely available to control invasive non-native plants, such as Diquat, have now been banned in many European countries, and the scale of occurrence and rate of spread of some invasive riparian weeds, now present in Europe, demands for a catchment scale control approach which is often unachievable with traditional methods due mainly to the sheer scale of the infestation and logistics required to coordinate efforts at such large scales.

Note: EU/national/local legislation on the use of plant protection products and biocides needs to be respected.

EFFECTIVENESS OF MEASURE

Himalayan balsam can be controlled by spraying the foliage with glyphosate (Kelly *et al*., 2008). The specific herbicide used and the timescale needed to achieve eradication will depend on factors such as the infestations proximity to watercourses and the local wildlife.

EFFORT REQUIRED

There is a high level of variation of seed production between habitats and individuals (Willis and Hulme, 2004), an individual plant can produce up to 2,500 seeds and propel the seeds up to 5-7 metres from the parent plant. When Himalayan balsam forms monocultures this can equate to a seed rain of 5,000-6,000 seeds m^{-2} (Beerling and Perrins, 1993).

Chemical control must be repeated over a number of seasons to ensure the seed bank is exhausted. The seed bank is relatively short-lived persisting between 18 to 24 months (Beerlings and Perrins, 1993), though seeds can remain viable for several years under artificial conditions with germination being achieved following a period of stratification at 4°C (Mumford, 1990). Thus, it is recommended that repeated visits to managed sites should be continued for at least three years (Tanner, pers. comm., 2017).

RESOURCES REQUIRED

Resources are likely to be similar to that detailed in *Rapid eradication: Resources required.* However, additional costs would be needed for chemicals, equipment and transportation of the equipment to infested sites. Resources would include equipment for example sprayer backpack (€150), staff time, travel costs, safety equipment. Repeated visits would be needed over 2 or 3 seasons.

SIDE EFFECTS

Often there are restrictions on the chemical that can be used, if any, due to the sensitivity of the invaded habitat. Non-target damage of native plants is a negative effect of this control method. Glyphosate® application is effective against Himalayan balsam (Stensones and Garnett, 1994) but will also kill other plants growing close by (1-2 m from the target plant).

ACCEPTABILITY TO STAKEHOLDERS

Chemical control may be viewed negatively by stakeholders due to potential non-target damage. In addition, there will be many areas where chemical application is not allowed for example in the near vicinity of standing water, such as along rivers, sites of scientific interest and of conservation value, etc.

ADDITIONAL COST INFORMATION

Implementation cost for Member States: Control costs range from €0.6 m^{2-1} (for chemical application or manual control by strimming) to €11.6 m^{2-1} when habitat restoration is included (Tanner *et al*., 2008; CABI, 2015).

Cost of inaction: See section in *Prevention: A ban on keeping, importing, selling, breeding and growing as required under Article 7 of the IAS Regulation*.

Cost-effectiveness of the measure: Chemical control can be used for high density large populations but the use of herbicides near a watercourse is restricted. Although there are no detailed figures on the area most suitable for chemical application, the author considers that control is achievable where the population is below 5,000 m^2.

Socio-economic aspects: See section in *Rapid eradication: Additional cost information*.

LEVEL OF CONFIDENCE[1]

A **moderate** level of confidence has been given for chemical control under rapid eradication. This is because the use of chemicals in the environment is highly restricted especially in areas where Himalayan balsam is known to invade and flourish, such as riparian habitats.

1 See Appendix

Measures for the species' management.

Chemical control.

MEASURE DESCRIPTION

Both selective herbicides such as 2, 4-D and triclopyr, and non-selective herbicides such as glyphosate are detailed as suitable in controlling Himalayan balsam (Kelly *et al.*, 2008). According to the locally applicable law, a permit may be required to use herbicides, in particular near water bodies. It should be noted however, that chemicals which were once widely available to control non-native invasive plants, such as Diquat®, have now been banned in many European countries, and the scale of occurrence and rate of spread of some invasive riparian weeds, now present in Europe, demands for a catchment scale control approach which is often unachievable with traditional methods due mainly to the sheer scale of the infestation.

Note: EU/national/local legislation on the use of plant protection products and biocides needs to be respected.

EFFECTIVENESS OF MEASURE

The use of herbicides can be effective control measure for Himalayan balsam (Kelly *et al.*, 2008). The specific herbicide used and the timescale needed to achieve eradication will depend on factors such as the infestations proximity to watercourses and the local wildlife.

The Dee-catchment partnership state 'Chemical control can be used for high density large populations but the use of herbicides near a watercourse is restricted. Chemical control can take up to two years to eradicate the plant (with additional monitoring following this). Initial treatment should be carried out from May to early July, with follow-up visits to remove any late flowers (and prevent seeding)' (see http://www.deepartnership.org/himalayan-balsam.asp).

Total eradication from an area may be impossible if neighbouring habitats harbour populations (Wadsworth *et al.*, 1997; Wadsworth *et al.*, 2000). Where the species occurs along a river system, a catchment-scale approach to control is the only realistic method to control this species, however, such a concerted approach is often difficult with traditional methods due to multiple land ownership along riparian systems and inaccessible habitats.

The Wye Valley (2009) carried out trials of glyphosate application using three concentrations: Compartment 1. 2 litres/hectare in 200 litres water, Compartment 3. 3 litres/hectare in 200 litres water and Compartment 5. 4 litres/hectare in 200 litres water. All concentrations of Glyphosate appeared to work equally well (Wye Valley, 2009).

Additional benefits include (Shropshire Hills, 2014):

- Control can be carried out well into the flowering season (June -July) but early enough to prevent seeding with the aim of minimising regeneration.
- Can be used in areas which are otherwise hard to reach.
- Spray just needs to partly touch the plant as the chemical is systemic.
- Small infestations can be controlled using a weed wiper
- A long-lance sprayer may assist in the spraying of less accessible areas out of the reach of conventional knapsack sprayers.
- Plant dies *in situ*; no collection needed.
- Quick method of control.

Negatives:

- Only possible to be undertaken by those trained in knapsack sprayers (certification required where not undertaken by owner of land).
- Problematic in publicly accessible areas.
- Operator error presents risk of missing some plants.
- Maximum recommended dosage by Monsanto for glyphosate unnecessarily high and costly (2).
- Collateral damage; all plants in vicinity affected where glyphosate used so compounding problems of soil erosion during high river flows.
- Application reliant on weather conditions.
- Significant restrictions on use.

EFFORT REQUIRED

Repeated applications may be required over 2 or 3 seasons to exhaust the short-lived seed bank. The seed bank is relatively short-lived persisting between 18 to 24 months (Beerlings and Perrins, 1993), though seeds can remain viable for several years under artificial conditions with germination being achieved following a period of stratification at 4°C (Mumford, 1990). Thus, it is recommended that repeated visits to managed sites should be continued for at least three years (Tanner, pers. comm., 2017).

RESOURCES REQUIRED

Resources are likely to be similar to that detailed in *Rapid eradication: Resources required.* However, additional costs would be needed for chemicals, equipment and transportation of the equipment to infested sites. Resources include: equipment for example sprayer backpack (€150), staff time, travel costs, safety equipment. Repeated visits would be needed over 2 or 3 seasons.

SIDE EFFECTS

Often there are restrictions on the chemical that can be used, if any, due to the sensitivity of the invaded habitat. Non-target damage of native plants is a negative effect of this control method (Wye Valley, 2009). Glyphosate® application is effective against Himalayan balsam (Stensones and Garnett, 1994) but will also kill other plants in the near vicinity.

ACCEPTABILITY TO STAKEHOLDERS

Any control of Himalayan balsam may be viewed negatively by some members of the public. The species has an extended flowering time compared to other European natives (Prowse and Goodridge, 2000), and coupled with high rates of sugar production, this plant is favoured by beekeepers (Showler, 1989; Starý and Tkalcu, 1998). The recent decline in the populations of bees (Feltwell, 2010; Blake *et al.*, 2011) has further highlighted the potential use this species may have in maintaining their populations (Showler, 1989). Apart from the potential benefits to Bombus populations, there are no other benefits of this species to the countryside, apart, of course, to the few that consider monocultures of the plant in flower an attractive addition.

Chemical control may be viewed negatively by stakeholders due to the non-target damage.

In addition, there will be many areas where chemical application is not allowed.

ADDITIONAL COST INFORMATION

Implementation cost for Member States: Control costs range from €0.6 m^{2-1} (for chemical application or manual control by strimming) to €11.6 m^{2-1} when habitat restoration is included (Tanner *et al.*, 2008, CABI, 2017).

Cost of inaction: See section in *Prevention: A ban on keeping, importing, selling, breeding and growing as required under Article 7 of the IAS Regulation.*

Cost-effectiveness of the measure: Chemical control is cost-effective when controlling small populations.

Socio-economic aspects: See section in *Rapid Eradication: Additional cost information.*

LEVEL OF CONFIDENCE[1]

A **moderate** level of confidence has been given for chemical control under management. This is because the use of chemicals in the environment is highly restricted especially in areas where Himalayan balsam is known to invade, such as riparian habitats.

1 See Appendix

Mechanical control.

MEASURE DESCRIPTION

Mechanical control can take the form of cutting using basic hand-held non-motorised utensils or motorised machinery such as mowers or strimmers. Larger agriculture machinery may be used in more open habitats.

EFFECTIVENESS OF MEASURE

Best results are achieved by applying mechanical control late in the season, for example, when the plants are in flower or beginning to flower (Tanner, pers. comm., 2017). Early cutting of the plants below the first node can control populations though this is labour intensive. In Germany, several mechanical methods have been tested (Hartmann *et al*., 1995), and mowing with or without removal of the plant material, mulching or soil cultivation have all been successful. In larger stands and where soil conditions permit, agricultural machinery may be used. Where the soil is wet and soft, heavy machinery will damage the soil and provide open spaces ideal for re-establishment.

As an annual Himalayan balsam can be easily controlled compared to perennial invasive plants. However, any control must aim at preventing the plants from setting seed.

Mechanical control is effective for controlling large stands of the species (Kelly *et al*., 2008).

In smaller stands, hand-held brush cutters can be used and hand-pulling of the plants is also feasible. In such cases, care has to be taken that pulled plants find no chance to re-grow where they are deposited. For lasting success, the area should be monitored for re-growth.

Hand-pulling is effective for eradicating small stands although it can leave banks bare and without root systems to hold soil in place, thereby adding to the potential for erosion.

However, cutting or spraying must be carefully timed, in June, to incorporate all plants at various growth stages and to prevent seed set (Prach, 1994). Cutting should sever the plant below the lowest node, preventing future seed set (Howell, 2002).

Total eradication from an area may be impossible if neighbouring habitats harbour populations (Wadsworth *et al*., 1997; Wadsworth *et al*., 2000).

Where the species occurs along a river system, a catchment-scale approach to control is the only realistic method to control this species, however, such a concerted approach is often difficult with traditional methods due to multiple land ownership along riparian systems and inaccessible habitats.

EFFORT REQUIRED

Repeated control may be required over 2 or 3 seasons to exhaust the short-lived seed bank. The seed bank is relatively short lived persisting between 18 to 24 months (Beerlings and Perrins, 1993), though seeds can remain viable for several years under artificial conditions with germination being achieved following a period of stratification at 4°C (Mumford, 1990). Thus, it is recommended that repeated visits to managed sites should be continued for at least three years (Tanner, pers. comm.).

RESOURCES REQUIRED

Resources are likely to be similar to that detailed in *Rapid eradication: Resources required.* However, additional costs would be needed for equipment and transportation of the equipment to infested sites. Resources required include strimmers (€150 each), staff time, travel costs, safety equipment. Repeated visits would be needed over 2 or 3 seasons.

SIDE EFFECTS

Along riparian habitats (one of the major habitats for this species within the EU), mechanical control measures can be effective for eradicating small stands, although it can leave banks bare and without root systems to hold soil in place, thereby adding to the potential for erosion (Tanner and Gange, 2013).

ACCEPTABILITY TO STAKEHOLDERS

Any control of Himalayan balsam may be viewed negatively by some members of the public.

The species has an extended flowering time compared to other European native species (Prowse and Goodridge, 2000), and coupled with high rates of sugar production, this plant is favoured by beekeepers (Showler, 1989; Starý and Tkalcu, 1998)). The recent decline in the populations of bees, (Feltwell, 2010; Blake *et al*., 2011) has further highlighted the potential use this species may have in maintaining their populations (Showler, 1989). Apart from the benefits to Bombus populations, there are no other benefits of this species to the countryside, apart, of course, to the few that consider monocultures of the plant in flower an attractive addition.

ADDITIONAL COST INFORMATION

Implementation cost for Member States: Control costs range from €0.6 m^{-1} (for chemical application or manual

control by strimming) to €11.6 m^{-1} when habitat restoration is included (Tanner *et al*., 2008, CABI, 2015).
Implementation costs will be relatively low and engagement with the local Wildlife Trusts or river Trusts and utilisation of the volunteer network can further reduce costs.

Some regional training workshops could be conducted to train stakeholders in identification, management and safety aspects where each training workshop may cost in the region of €3000.

Cost of inaction: See section in *Prevention: A ban on keeping, importing, selling, breeding and growing as required under Article 7 of the IAS Regulation*.

Cost-effectiveness of the measure: Mechanical control is a cost-effective method for controlling Himalayan balsam especially when NGOs are utilised.

Socio-economic aspects: See section in *Rapid Eradication: Additional cost information.*

LEVEL OF CONFIDENCE[1]

A **high** level of confidence has been given for mechanical control under management. As long as the user has access to sites with infested populations, control would be feasible using this method. However, again, it should be highlighted that control must take place on a catchment scale and this is often impractical due to the habitats the plant grows in.

1 See Appendix

Impatiens glandulifera *flowers.© Zygmunt Dajdok.*

Manual control.

MEASURE DESCRIPTION

Manual control methods involve the physical pulling of individual Himalayan balsam plants. In the UK, this is often referred to as 'balsam bashing'. Often teams of volunteers go out on mass and remove Himalayan balsam plants from an area. Following removal, the plants are safely disposed of or composted.

EFFECTIVENESS OF MEASURE

Best results are achieved early in the season, before the plant has flowered and set seed. The measure is very effective at removing both small and large populations in discrete areas. Himalayan balsam has a shallow root system and can be pulled up from the ground with little effort.

As an annual the species can be easily controlled compared to perennial invasive plants. However, any control must aim at preventing the plants from setting seed.

In smaller stands, hand-held brush cutters can be used and hand-pulling of the plants is also feasible. In such cases, care has to be taken that pulled plants find no chance to re-grow where they are deposited. For lasting success, the area should be monitored for re-growth.

Hand-pulling can leave banks bare and without root systems to hold soil in place, thereby adding to the potential for erosion. Hand pulling must be carefully timed, in June, to incorporate all plants at various growth stages and to prevent seed set (Prach, 1994).

Cutting should sever the plant below the lowest node, preventing future seed set (Howell, 2002).

Total eradication from an area may be impossible if neighbouring habitats harbour populations (Wadsworth *et al.*, 1997; Wadsworth *et al.*, 2000). Where the species occurs along a river system, a catchment-scale approach to control is the only realistic method to control this species, however, such a concerted approach is often difficult with traditional methods due to multiple land ownership along riparian systems and inaccessible habitats.

Additional positive effects of this method include (Shropshire Hills, 2014):

- Easy to pull.
- No risk of leaving a node occurs if completed properly (for example, no risk of regrowth).
- Whole plant can be systematically laid out for collection and disposal.
- Quick method of control in areas of sparse Himalayan balsam.
- Targeted; surrounding native species unaffected.
- Exposes soil to more light and the promotion of further seedlings to germinate; any late emerging plants may be dealt with.
- Possible to be undertaken by volunteer.

Negatives:

- Physically demanding.
- Labour intensive.
- Can be a slow process.
- Expensive if carried out by contractors.

EFFORT REQUIRED

Repeated applications may be required over 2 or 3 seasons may be needed to exhaust the short-lived seed bank. Thus, it is recommended that repeated visits to managed sites should be continued for at least 3 years (Tanner, pers. comm., 2017).

Hand pulling can be labour intensive and often teams of volunteers spend full days in the field pulling plants. The IRD Duhallow LIFE Project (2015) used up to eight people per group per day. Additional effort is required to dispose of the plant material following uplifting.

RESOURCES REQUIRED

Little physical resources are needed for this management method compared to chemical or mechanical control, with the exception of human hours. Safety clothes should be worn, and these clothes should be selected for depending on the habitat where the manual control is to take place. For example, waterproof boots may be required when working near water bodies. If using volunteers, some level of basic training would be required to ensure they can identify Himalayan balsam in the field.

Some logical coordination is also required to manage volunteer groups.

SIDE EFFECTS

Along riparian habitats (one of the major habitats for this species within the EU), manual control measures can be effective for eradicating small stands, although it can leave banks bare and without root systems to hold soil in place, thereby adding to the potential for erosion.

In addition, Himalayan balsam has a lack of dependence on arbuscular mycorrhizal fungi (AMF) and thus where the species invades and dominates an area over time, AMF may potentially become depauperate at a cost to AMF dependent native plant species. There have been no studies on the effect of manual management of non-native invasive species on the soil mycobiota. However, in other systems, such as agricultural fields, manual disturbance of the soil has been shown to change the quality and quantity of AMF (Jansa *et al*., 2003; Curaqueo *et al*., 2011).

Manual and mechanical control of the species may potentially intensify the disturbance of the microbial community by further disrupting and depleting the AMF network (Tanner and Gange, 2013). Those native plant species that are dependent on AMF for their colonisation may decline while the non-native species benefit due to the lack of competition (Reinhart and Callaway, 2006).

ACCEPTABILITY TO STAKEHOLDERS

Manual control would be perceived as more environmentally acceptable to stakeholders compared to chemical application.

ADDITIONAL COST INFORMATION

Implementation costs for Member States: Implementation costs will be relatively low and engagement with the local environmental NGOs and utilisation of the volunteer network can further reduce costs.

Some regional training workshops could be conducted to train stakeholders in identification, management and safety aspects where each training workshop may cost in the region of €3000.

Control costs range from €0.6 m^{2-1} (for chemical application or manual control by strimming) to €11.6 m^{2-1} when habitat restoration is included (Tanner *et al*., 2008, CABI, 2015).

Cost of inaction: See section in *Prevention: A ban on keeping, importing, selling, breeding and growing as required under Article 7 of the IAS Regulation*.

Cost-effectiveness of the measure: Manual control is a cost-effective method for controlling Himalayan balsam especially when NGOs are utilised.

Socio-economic aspects: See section in *Rapid eradication: Additional cost information*.

LEVEL OF CONFIDENCE[1]

A **high** level of confidence has been given to manual control under this management section as the species has been effectively managed using this methodology.

1 See Appendix

Biological control.

MEASURE DESCRIPTION

Since 2006, research has been conducted on the classical biological control of Himalayan balsam (Tanner 2008, Tanner *et al*., 2015a/b). Classical biological control is defined as the utilisation of natural enemies in the regulation of host populations (DeBach, 1964).

Since 2006, research has been conducted on the biological control of Himalayan balsam, where numerous surveys for natural enemies have been conducted throughout the plants native range (India and Pakistan) (Tanner *et al*., 2015). Due to the high level of damage observed in the field, the rust fungus *Puccinia komarovii* was prioritised for further study. Cross inoculation studies revealed a high level of specificity of this rust towards Himalayan balsam and as such, the rust was renamed as a variety, *P. komarovii* var. *glanduliferae* (Tanner *et al*., 2015a, b).

Experiments were conducted to determine the lifecycle of the rust which revealed that it is a macrocyclic (has all five spore stages) and autoecious (completes its lifecycle on Himalayan balsam only) species (Tanner *et al*., 2015a/b). Host-specificity testing assessed 75 non-target plant species and proved that the rust is a true specialist to its natural host Himalayan balsam (Tanner *et al*., 2015). A Pest Risk Assessment (PRA), which fully detailed the research conducted on the host-range, lifecycle and ecology of the rust was submitted to FERA in 2014; this was followed by a public consultation.

The PRA underwent further evaluation by the European Commission's Standing Committee on Plant Health and following their feedback Defra Ministers approved the release of an isolate from India in July 2014.

Since then, the rust has been released at selected sites in England and Wales. Further details of rust releases in the UK can be found in Varia *et al.* (2016). Additional information on the biological control programme is available via the website: http://www.cabi.org/projects/project/32944

Note: It should be borne in mind that the release of macro-organisms as biological control agents is currently not regulated at EU level. Nevertheless national/regional laws are to be respected. Before any release of an alien species as a biological control agent an appropriate risk assessment should be made.

EFFECTIVENESS OF MEASURE

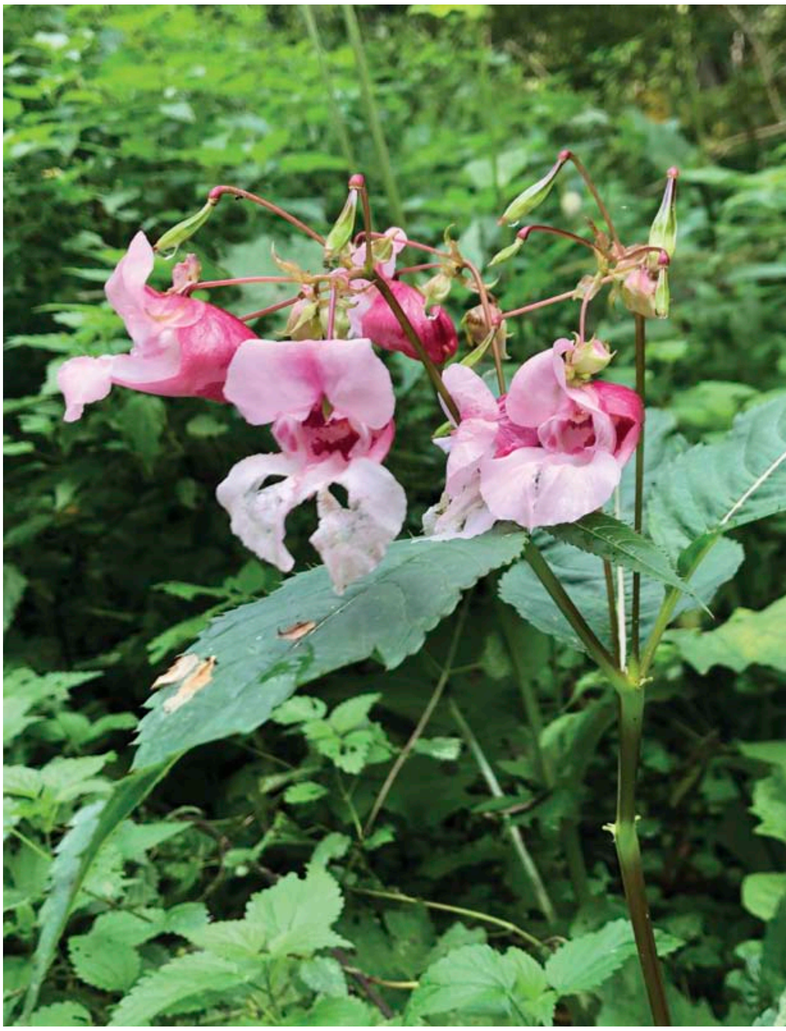
At present the biological control programme is in its establishment phase where the biological agent is being released and monitored in the field in the UK.

There have not been any previous attempts at biological control of Himalayan balsam in Europe, or worldwide, and there have not been any attempts at utilising this method against any closely related species.

EFFORT REQUIRED

Biological control has its drawbacks, as it is not a quick fix solution (Shaw, 2003). Any impacts on the target weed may take time to be seen in the field. The classical biological control agent needs to establish, adapt to its new environment, and build up the population and disperses, before any impacts on the target species are seen.

As a classical biological control agent, in principle, the rust could be released just once into the environment (a region or country) and establish and spread on its own accord. However, to maximise the potential for establishment additional releases may be required.



Impatiens glandulifera *is a large annual plant native to the Himalayas. © Aleksander Niweliński.*

RESOURCES REQUIRED

Biological control programmes can be expensive; however, a significant amount of research has been conducted for Himalayan balsam by the UK and most of the species tested in the host range testing are relevant to the whole of the EU. However, to satisfy regulators and the general public, further testing of key species nay be required for each country where the biocontrol agent is considered for release and this would cost in the region of €50,000 per country (Shaw, pers. comm., 2017). Further funding would be required to monitor the biological control agent in the field post release. This may cost in the region of €30,000 year, per country (based on monitoring programmes in the UK).

SIDE EFFECTS

Classical biological control against invasive alien plant species come with the associated benefits, a single release may control and reduce the vigour, occurrence and impact of the invasive population on a geographical scale that would be difficult to achieve with more traditional methods (Tanner *et al*., 2015 a; van Wigen *et al*.,2004).

On the downside, biological control will not eradicate a weed population (Shaw, 2003) and even a high level of control may take many years (Fowler and Holden, 1994) as the population of the agent builds in the new environment.

ACCEPTABILITY TO STAKEHOLDERS

Any biological control of Himalayan balsam may be viewed negatively by some members of the public. For biological control, the perception of risk may be greater than that of other control methods.

ADDITIONAL COST INFORMATION

Implementation costs for Member States: To satisfy regulators and the general public, further testing of key species may be required for each country where the biocontrol agent is considered for release and this would cost in the region of €50,000 per country (R. Shaw, pers. comm., 2017).

Cost of inaction: See section in *Prevention: A ban on keeping, importing, selling, breeding and growing as required under Article 7 of the IAS Regulation*. In addition, control costs range from €0.6 m^{2-1} (for chemical application or manual control by strimming) to €11.6 m^{2-1} when habitat restoration is included (Tanner *et al*., 2008; CABI, 2017).

Cost-effectiveness of the measure: To satisfy regulators and the general public, further testing of key species would be required for each country where the biocontrol agent is considered for release and this would cost in the region of €50,000 per country (R. Shaw, pers. comm., 2017).

Socio-economic aspects: When successful, a biological control programme can save countries millions of Euros in lost revenue and an unquantifiable figure in terms of ecosystem preservation (Tomley and Evans, 2004; Shaw e*t al*., 2011). As the more traditional control methods are failing to suppress Himalayan balsam on a national and local scale, or as part of an integrated pest management programme, biological control offers an alternative approach which could reduce the occurrence of the species to an acceptable level, making it more amenable to control using traditional methods (for example, chemical or manual control), in an economic and ecological way.

LEVEL OF CONFIDENCE[1]

Moderate – at the present time the biological control of Himalayan balsam has not shown any impact on its host or the population as it is currently in the establishment phase of the release programme. It should be noted however, that the release programme is still in its early phase and impacts on the target population (such as a decline in abundance) can take up to 7-10 years.

1 See Appendix

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Appendix

Level of confidence provides an overall assessment of the confidence that can be applied to the information provided for the measure.

- **High:** Information comes from published material, or current practices based on expert experience applied in one of the EU countries or third country with similar environmental, economic and social conditions.

- **Medium:** Information comes from published data or expert opinion, but it is not commonly applied, or it is applied in regions that may be too different from Europe (for example tropical regions) to guarantee that the results will be transposable.

- **Low:** data are not published in reliable information sources and methods are not commonly practiced or are based solely on opinion. This is for example the case of a novel situation where there is little evidence on which to base an assessment.

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