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The management of Asiatic tearthumb (*Persicaria perfoliata*)

Measures and associated costs

Scientific name(s)	*Persicaria perfoliata* (L.) H. Gross
Common names (in English)	Asiatic tearthumb
Synonym	*Polygonum perfoliatum L.*
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Date of completion	09/09/2019
Citation	Tewksbury, L. 2019. Information on measures and related costs in relation to species included on the Union list: *Persicaria perfoliata*. Technical note prepared by IUCN for the European Commission.

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Common names

BG	Пробитолистно пипериче
HR	Prorasla perzikarija
CZ	Rdesno
DA	Spydbladet pileurt
NL	Gestekelde duizendknoop
EN	Asiatic tearthumb
ET	Haakuv kirbutatar
FI	Raastotatar
FR	Renouée perfoliée
DE	Durchwachsener Knöterich
EL	–
HU	Ördögfarok keserűfű
IE	Fíniún Rúiseach
IT	–
LV	–
LT	Raizgusis rūgtis
MT	–
PL	–
PT	–
RO	–
SK	Horčiak
SL	Plezajoča dresen
ES	–
SV	Gisselpilört

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

PREVENTION OF UNINTENTIONAL INTRODUCTIONS

The species is only known to have been introduced unintentionally, primarily as a contaminant of nursery stock with growing media and of soil as a commodity. Therefore this pathway can only be addressed through stricter national phytosanitary inspections and practices that are currently required at the EU level.

PREVENTION OF SECONDARY SPREAD

Once established, seeds of the species are spread by birds, mammals and water, but also by machinery and vehicles, such as logging equipment, and as a contaminant of nursery plants and soil. Therefore in terms of preventing secondary spread, awareness campaigns targeting key sectors (for example forestry, horticulture) can be run to promote biosecurity best practices such as cleaning vehicles and restricting movement of soil.

EARLY DETECTION

Engagement with these same sectors will also improve early detection measures as the species has a history (in the USA) of being found at nursery sites.

RAPID ERADICATION

In cases of early detection, manual removal (hand pulling) is an effective way to rapidly eradicate *P. perfoliata* while populations are young and small. Eradication and management measures need to address how to prevent fruiting and decrease soil seed banks of *P. perfoliata*.

MANAGEMENT

The three management options that are most widely used to control *Persicaria perfoliata* (Asiatic tearthumb) are mechanical removal, herbicide use, and classical biological control. Mechanical removal is effective in small areas, and especially with young seedlings, but it is very critical to apply mechanical removal before fruit set and repeat removal measures annually as it can take years to achieve successful removal (Stone, 2010; Travis and Kiviat, 2016). Selective herbicides can also be effective, but have associated economic and environmental costs. Lake *et al.,* (2014) showed that one-time application of pre-emergence herbicide could be enough to provide control of *P. perfoliata* at least during the following three years (test duration). Other protocols call for pre- and post-emergence herbicide application (herbicide application twice a year) (Glover, 2013).Classical biological control has been successful in reducing seed production, reducing density of Asiatic tearthumb and slowing its spread. An emerging management measure option is the integrated management of *P. perfoliata*. The integration of biological control, selective herbicides, and seeding of native plants appears to be a very promising long term management plan for *P. perfoliata* (Cutting and Hough-Goldstein, 2013) Initial herbicide use allows native plants to get a competitive advantage on *P. perfoliata* as the population of biocontrol agents (weevils) is getting established. Grazing with livestock is also a promising measure of management, suitable for integrated management, but additional studies are necessary.

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 *P. perfoliata.*

MEASURE DESCRIPTION

As the species is listed as an invasive alien species of Union concern, the following measures will automatically apply, in accordance with Article 7 of the EU IAS Regulation 1143/2014:

Invasive alien species of Union concern shall not be intentionally:

(a) brought into the territory of the Union, including transit under customs supervision;
(b) kept, including in contained holding;
(c) bred, including in contained holding;
(d) transported to, from or within the Union, except for the transportation of species to facilities in the context of eradication;
(e) placed on the market;
(f) used or exchanged;
(g) permitted to reproduce, grown or cultivated, including in contained holding; or
(h) released into the environment.

Also note that, in accordance with Article 15(1) – As of 2 January 2016, Member States should have in place fully functioning structures to carry out the official controls necessary to prevent the intentional introduction into the Union of invasive alien species of Union concern. Those official controls shall apply to the categories of goods falling within the Combined Nomenclature codes to which a reference is made in the Union list, pursuant to Article 4(5).]

Therefore measures for the prevention of intentional introductions do not need to be discussed further in this technical note.

Phytosanitary inspections and best practices on imports of plants for planting, soil and growing media.

MEASURE DESCRIPTION

The primary pathway of unintentional introduction is as a contaminant of nursery stock with growing media (for example *Rhododendron* stock, forestry trees), and of soil/growing media as a commodity (Stone 2010; EPPO, undated). In addition, *P. perfoliata* was introduced in the mid 1930's into Stewartstown, Pennsylvania (USA) in the Gable Nursery, most likely with the importation of holly (*Ilex*) seeds (Moul, 1948). Therefore effective *pre-border* (pre-import) phytosanitary measures and *at border* phytosanitary inspections would need to be implemented for the species for all high risk imports of soil/growing media as a commodity and of nursery stock with growing media from areas where *P. perfoliata* is present in order to address these pathways of introduction. *P. perfoliata* is native to large parts of Asia, and Russia(Siberia), is an invasive alien species in North America, has alien populations known to be present in Turkey (Brundu *et al.,* 2011), and is recorded as a 'casual' (alien) species in New Zealand (CABI, 2019; Wilton *et al.,* 2016).

Pre-border best practices that could be adopted include a pest-free place of production, plants grown in containers with sterilized growing media, or only allowing the import of plants free from growing media (especially from countries where *P. perfoliata* is present, EPPO (undated)).The IPPC have produced an international standard for phytosanitary measures (ISPM 40), on the international movement of growing media in association with plants for planting (IPPC, 2017a), and describe the measures to manage the pest risk (including from seeds) of growing media associated with plants for planting in international movement.

Phytosanitary measures associated with plants for planting and growing media is regulated through the EU's existing plant health regulations, the requirements of which do not currently cover seeds in growing media (EPPO, undated). Currently in the EU, the importation of soil in association with plants and soil and growing media is regulated by Council Directive 2000/29/EC *on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community* [Plant Health Directive] (EC 2000) (soon to be replaced by Regulation (EU) 2016/2031 which comes into force on 14th December 2019). Under the Plant Health Directive *P. perfoliata* is not considered a regulated pest ('harmful organism'), therefore phytosanitary measures do not need to be applied and seeds of the pest may be present in plants for planting accompanied with growing media coming from Asia and from North-America (EPPO ,undated). Note that since the species was added to the List of invasive alien species of Union concern in 2016 (under the EU IAS Regulation 1143/2014) it cannot also be regulated under the Plant Health Directive as a 'harmful organism' and therefore requiring phytosanitary measures.

However, the measures put in place by the Plant Health Directive may provide some degree of prevention.

The conditions set out under the Directive have recently been tightened by amendments established through Implementing Directive (EU) 2019/523 (EC 2019). The Directive now (as of 1st September 2019) prohibits the import of soil and growing media as such[1] from all third countries, apart from Switzerland (prior to recent amendments it was prohibited from most third countries[2]). In addition, the Directive imposes *special requirements* (see below) and requires a plant health inspection and a phytosanitary certificate for all imports of growing medium, attached to or associated with plants, from all countries apart from Switzerland (again, prior to amendments this was required for all imports from most third countries[2]). However as noted above, *P. perfoliata* will still not be considered a regulated 'harmful organism' (under the Plant Health Directive) and therefore phytosanitary measures will not target this species specifically. The *special requirements* require an Official statement that:

(a) the growing medium, at the time of planting of the associated plants:

(i) was free from soil and organic matter and not previously used for growing plants or for any agricultural purposes,

or

(ii) was composed entirely of peat or fibre of *Cocos nucifera* L. and not previously used for growing plants or for any agricultural purposes

or

(iii) was subjected to effective treatment to ensure freedom from harmful organisms and the treatment data should be indicated on the certificates referred to in Article 13(1)(ii) under the rubric 'Additional declaration'

and

in all the above cases was stored and maintained under

1 Soil and growing media as such consists in whole or in part of soil or solid organic substances such as parts of plants, and humus, which includes peat or bark, other than that composed entirely of peat

2 Turkey, Belarus, Moldavia, Russia, Ukraine and third countries not belonging to continental Europe, other than Cyprus, Egypt, Israel, Libya, Malta, Morocco, Tunisia.

appropriate conditions to keep freedom from harmful organisms

and

(b) since planting:

(i) appropriate measures have been taken to ensure that the growing medium has been kept free from harmful organisms, including at least:

— physical isolation of the growing medium from soil and other possible sources of contamination

— hygiene measures

— using water free from harmful organisms

or

(ii) within two weeks prior to export the growing medium including, where appropriate, soil has been completely removed by washing using water free from harmful organisms. Replanting may be performed in the growing medium that shall meet the requirements laid down in point (a). Appropriate conditions shall be maintained to keep freedom from harmful organisms as stipulated in point (b).'

In summary, these new amendments to the Plant Health Directive will prohibit all imports of soil and growing media as a commodity from all third countries (apart from Switzerland), but will still allow the import of soil and organic matter as a growing medium, attached to or associated with plants, as long as it is subjected to effective treatment to ensure it is free from 'harmful organisms', but critically not targeting *P. perfoliata* specifically. These measures are still not as strict as some other countries, such as Australia[3] where soil is not allowed to be imported, and plants imported for planting need to be free from all growing media (including soil, peat etc.).

However, additional phytosanitary inspections and best practices targeting the species can be enacted at a National level. This could be assisted by molecular tools to aid in the identification of the species through inspections, and EPPO-Q-Bank[4], a database to support diagnostic activities on plant pests, is developing molecular sequence data for all invasive alien plant species of Union concern, and *P. perfoliata* will be added soon (van Valkenburg, J. pers. comm., 2019).

SCALE OF APPLICATION

This measure will need to be applied at a national level across the EU.

EFFECTIVENESS OF MEASURE

Unknown.

It is unlikely that the measures previously in place (such as prior to the recent amendments) were able to prevent the species from arriving in the EU (EPPO, 2007; O'Rourke and Lysaght, 2014), though to date the species has not been recorded in the EU. It is unknown if the stricter requirements now in place as per the amendments to the Plant Health Directive will be any more effective at preventing the introduction of *P. perfoliata*. As the species cannot be a regulated 'harmful organism' under the Plant Health Directive, phytosanitary measures will not be compulsory for the species at an EU level. Therefore increased phytosanitary inspections and best practices specifically targeting the species at a national level, or a prohibition on the import of all growing media attached to or associated with plants at an EU level, are the only measures that are likely to be effective for the species. However, the success of such measures also depends upon the efficacy of the inspections which can be improved through the use of molecular identification tools etc.

EFFORT REQUIRED

The inspections and other actions put in place under this measure would need to be in place permanently.

RESOURCES REQUIRED

Phytosanitary capacity to implement the requirements at a national level is already in place across the EU - as set out under Council Directive 2000/29/EC (EC, 2000), (soon to be replaced by Regulation (EU) 2016/2031). Additional capacity building for national plant health inspectors and identification guides of the species (incl. seeds) and best practices for effectively treating growing media, and preventing contamination of plants for import will be needed.

SIDE EFFECTS

Environmental: Positive

Social: Neutral or mixed

Economic: Negative

There may be some negative economic side effects to the horticultural sector if it affects the price of importing plants. However, stricter phytosanitary standards would prevent the unintentional introductions of other potential invasive alien species into the EU.

ACCEPTABILITY TO STAKEHOLDERS

Neutral or mixed.

There may be economic consequences to prohibition of exporting certain products.

ADDITIONAL COST INFORMATION

Unknown.

LEVEL OF CONFIDENCE*

Established but incomplete.

There are limited information sources on the measure for the species.

3 Australian Dept. Agriculture, Importing live plants into Australia http://www.agriculture.gov.au/import/goods/plant-products/how-to-import-plants [Accessed 12/07/19]

4 EPPO-Q-Bank https://qbank.eppo.int/plants/organisms

* See Appendix

Measures to prevent the species spreading once they have been introduced.

Awareness campaigns for land managers.

MEASURE DESCRIPTION

The species is known to be spread by natural dispersal, including along waterways as vines frequently hang over waterways and the seeds can remain buoyant for 7-9 days, during storm events the risk of spread greatly increases (EPPO, undated). Fruits can be numerous, and seeds can also be spread by birds, and mammals. Prevention of fruit set and dispersal of seed will be the best opportunity to prevent secondary spread of Asiatic tearthumb. Therefore eradication or management of the species is a critical measure for preventing secondary spread; these measures are described in the sections below.

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In addition to natural spread, seeds can be unintentionally spread by humans via nursery plants, logging equipment, machinery, and other means. Sharing information on invasive species dispersal mechanisms, impacts, and prevention and control strategies through invasive species networks enables land managers to more effectively respond to weed invasions (Simpson *et al*., 2009). Therefore an awareness raising campaign targeting land managers could be implemented focusing on engaging stakeholders in and around known infested areas. This should promote biosecurity best practices, such as cleaning equipment and machinery with a pressure washer to remove soil and seeds before moving off site, and restricting the movement of soil from infested or potentially invaded sites (seeds could remain viable in the soil also for six years (Hough-Goldstein *et al*., 2015). There are sector specific best management practices, such as for the logging sector (LeDoux and Martin, 2013). There is also an ISPM Standard 41 on International movement of used vehicles, machinery and equipment, which identifies appropriate phytosanitary measures to address risks associated with used vehicles, machinery and equipment (VME) utilized in agriculture, forestry, horticulture, earth moving, surface mining, waste management and by the military (IPPC 2017b). While this focuses on international movement of VMEs, aspects may still be relevant for addressing risks associated with local movement.

SCALE OF APPLICATION

Awareness campaigns can be run at national, sub-national or even local level. In the case of the EU, where the species is not yet present it is expected that this would be used in response to an early detection and therefore would only need to be applied at a relatively small scale.

EFFECTIVENESS OF MEASURE

Unknown.

It is unknown how effective awareness campaigns and the best management practices are. However, as this measure is likely to be applied in response to early detections, and therefore at a limited number of sites, it could be more effective than trying to address the secondary spread of an already established invasive alien species.

EFFORT REQUIRED

As the species is not yet present in the EU, it is expected that such awareness campaigns (if specifically targeting *P. perfoliata* early detection) would be relatively small and not require significant effort. If such best practices are desired to be implemented to address invasive alien species in general, then a much larger stakeholder engagement and outreach programme will be needed.

RESOURCES REQUIRED

In response to an early detection, resources would require staff time from the relevant government agency to engage with affected and potentially affected land managers, to raise awareness of the species and the best practices that need to be implemented. If a broader awareness campaign is run (to address a wide range of invasive alien species) possibly at a national level, the development of sector specific guidance (or codes of conduct) may be needed to be developed with relevant sectors.

SIDE EFFECTS

Environmental: Positive

Social: Neutral or mixed

Economic: Neutral or mixed

An awareness raising campaign will raise awareness of invasive alien species in general with key stakeholders, and the resulting implementation of best practices to prevent the spread of *P. perfoliata* species will also address other IAS that share the same pathway of secondary spread.

ACCEPTABILITY TO STAKEHOLDERS

Neutral or mixed.

The awareness campaign itself should be acceptable to most stakeholders. Some land managers may resist implementing best practices on their land.

ADDITIONAL COST INFORMATION

No information.

LEVEL OF CONFIDENCE*

Established but incomplete.

There are some best management practices that exist but information is lacking on measures specifically for this species.

* See Appendix

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

Outreach to key sectors.

MEASURE DESCRIPTION

As the species is most likely to be introduced via contaminants of nursery material or soil, key sectors such as the horticulture and forestry sector should be engaged to raise awareness of the species (and ideally other relevant IAS of Union concern) and facilitate reporting of any detection. In North America the species has a history of being found at nursery sites (Miller and Connolly, 2018). However, it is important to note that seeds may not initially germinate and can be viable in the soil 3 to 6 years (van Clef and Stiles, 2001 in O'Rourke and Lysaght, 2014, and Hough-Goldstein *et al.,* 2015), by which time the imported plants and associated growing material could be planted.

The species is relatively easy to identify and can grow up to 6m long (15cm a day in ideal conditions) until frost (Global Invasive Species Database, 2019). The species is known to invade wetland and floodplains, along waterways, and in moist forests and woodlands, as well as in upland disturbed sites. It also occurs along forests, roads, and trail edges and in canopy gaps in forests (Travis and Kiviat, 2016). A study on range expansion of *P. perfoliata* found that it fails to persist under moisture deficiency, therefore it has a limited potential to expand to dry areas (Farooq, 2017). It optimally performs in moist and good light conditions (O'Rourke and Lysaght, 2014), and while it can tolerate partial shade, dense shade can retard its growth. Moist and cold are necessary to break seeds dormancy (Hought-Goldstein *et al.*, 2015).

Existing identification guides for species already exist, for example by Southern Indiana Cooperative Invasives Management[5], and Michigan State University[6].

SCALE OF APPLICATION

Best applied at the national scale through relevant trade sector bodies.

EFFECTIVENESS OF MEASURE

Unknown.

The effectiveness of the measure is unknown.

EFFORT REQUIRED

Unknown.

RESOURCES REQUIRED

The production of identification guides and staff time for engagement activities.

SIDE EFFECTS

Environmental: Neutral or mixed
Social: Neutral or mixed
Economic: Neutral or mixed

There should be few side effects to this measure, but any environmental, social, and economic effects, such as increased awareness of invasive species, protection of native species, and reduced economic loss due to new invasions are likely to be positive.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

The measure should be acceptable to all stakeholders.

ADDITIONAL COST INFORMATION

No information available.

LEVEL OF CONFIDENCE*

Unresolved.

There is little information available for early detection through engaging with key sectors.

5 https://www.extension.purdue.edu/extmedia/fnr/fnr-481-w.pdf
6 https://mnfi.anr.msu.edu/invasive-species/InvasivePlantsFieldGuide.pdf

* See Appendix

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

Manual removal.

MEASURE DESCRIPTION

The species has shallow fibrous roots and it can re-sprout from the basal stem if not properly cut (Travis and Kiviat, 2016; Glover, 2013), moreover, *P. perfoliata* might adopt a perennial life cycle in wet, warm climate (CABI, 2019) and in China as perennial plant formed new roots from nodes on climbing stems and developed into new plants producing flowers and fruits (Wu *et al*., 2002). Therefore manual removal through hand pulling is the most effective measure to achieve eradication at an early stage of invasion (Oliver, 1996; Travis and Kiviat, 2016), but several precautions must be taken.

The seedling stage is the most appropriate stage for this measure, and before fruit production which can begin in June (in North America) as harvesting after fruit production may facilitate dispersal (Global Invasive Species Database, 2019). This is because even if the fruit are not ripe a relevant percentage of seeds in green fruit are already viable (35% according to Travis and Kiviat, 2016). In order to make the measure more efficient and time-/cost-saving, manual removal should be done before the vine climbs on trees and surrounding vegetation. All plant material has to be removed and needs to be bagged on site and disposed of or burnt.

Based on site conditions, providing competition to *P. perfoliata* by seeding with native plants might also be needed.

SCALE OF APPLICATION

This can only be achieved for small recent invasions.

EFFECTIVENESS OF MEASURE

Effective.

Physical removal has worked well for small infestations in small areas; one example is a nursery in Rhode Island where *P. perfoliata* was eradicated after many years of hand pulling (Dick Casagrande, personal communication).

EFFORT REQUIRED

The measure may need to be repeated until the seed bank is depleted which can take between 3-6 years (Travis and Kiviat, 2016).

RESOURCES REQUIRED

Protective gloves and clothes (especially if undertaken after the barbs have hardened), access to transport and suitable disposal facilities.

SIDE EFFECTS

Environmental: Neutral or mixed

Social: Neutral or mixed

Economic: Neutral or mixed

There are no expected side effects to this measures.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

This measure should be acceptable for all stakeholders, as if the measure is not undertaken the species will quickly spread.

ADDITIONAL COST INFORMATION

No information available.

LEVEL OF CONFIDENCE*

Established but incomplete.

There are a number of sources citing hand removal as an effective measure for removal of small infestations but few reports of successful eradications in the literature (though this does not mean they have not occurred).

* See Appendix

Measures for the species' management.

Classical biological control.

MEASURE DESCRIPTION

Classical biological control of weeds is intended to provide long term management through the initiation of an herbivore – host plant relationship. It aims to reduce the competitive advantage of an established invasive alien plant mitigating its impacts, but will not lead to its eradication. It is important to note that currently *P. perfoliata* is not yet present within the EU, and if it were to be introduced it will hopefully be eradicated before it can become established.

P. perfoliata has successfully been controlled across North-eastern USA using a host specific classical biological control agent, the weevil *Rhinoncomimus latipes*. It was first undertaken in the Mid-Atlantic area of the United States in 2004, with releases occurring in 11 States up to 2013 (USDA Forest Service, undated). Since then, populations of the weevil have increased, reducing negative impacts of Asiatic tearthumb (Hough-Goldstein, 2011). Control using *R. latipes* can reduce cover and seed production, especially in warm and dry conditions (Hough-Goldstein, 2016). In addition this measure integrates well with other methods.

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There has been extensive research and implementation of classical biological control of *P. perfoliata* utilizing the weevil, *R. latipes*. It is possible that research may identify additional biological control agents that are safe and effective that will improve the effectiveness of the weevil. Known herbivores and pathogens in the native range of Asiatic tearthumb weed that could become potential biological control agents include *Colletotrichum cf. gloeosporioides*, an anthracnose pathogen of *P. perfoliata* (Berner and Cavin, 2012), and many additional insects in China and Japan (Ding *et al*., 2004 and Miura *et al*., 2008).

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.

SCALE OF APPLICATION

The biological control program using *Rhinoncomimus latipes* has been utilized over the area of the entire North-eastern U.S. The weevil established at a success rate of 96.9% of release sites, dispersed 4.3 km/year, and caused a reduction of 25% of the spring density of Asiatic tearthumb 2-3 years after release (Hough-Goldstein, 2009).

EFFECTIVENESS OF MEASURE

Effective.

A study on the impacts of the weevil, showed the presence of adult weevils led to a 37% reduction in the number of seed clusters (Smith and Hough-Goldstein, 2014). In addition, after 2-6 years a 25% reduction in density and a 7-week delay in seed maturation was recorded (Smith and Hough-Goldstein, 2014). Climatic conditions, such as prolonged cold and heavy rainfall periods, can influence performance of both *R. latipes* (negatively) and *P. perfoliata* (positively), resulting in a decrease of the control effectiveness (Hough-Goldstein *et al*., 2016).

There are state reports in the North-eastern U.S.A. of successful introductions of *R. latipes* that have extirpated small populations, killed seedlings, reduced Asiatic tearthumb density, and reduced seed production. In two New Jersey release sites the number of stems and the percent cover of Asiatic tearthumb dropped significantly from 2005 when weevils were released to 2017 (Hudson *et al.*, 2017). In Rhode Island (personal observation) small areas of Asiatic tearthumb have been extirpated after a significant release of *R. latipes* weevils.

P. perfoliata shows a high degree of patchiness in the landscape and often spreads into hard-to-access areas making visit-and-hand release approach challenging. Therefore the effectiveness of current biological control in North America could be increased by spatial targeting and precision release of *R. latipes* using unmanned aerial systems (Park *et al.*, 2018).

EFFORT REQUIRED

A single release of weevils may be sufficient to establish a population, however as the species will naturally spread 1.5-2.9m per week, multiple releases may be required depending upon the areas infested by *P. perfoliata*. In the USA a total 535,562 weevils have been released between 2004 and 2013 across 11 States (USDA Forest Service, undated). In addition, any release of a biological control agent will require long term monitoring.

RESOURCES REQUIRED

To establish and implement a classical biological control programme significant resources are required for the identification and testing of the agent, field trials, risk assessment, and release. Once the agent has established (as *R. latipes* has done in North America) costs will diminish, but long term monitoring is required.

SIDE EFFECTS

Environmental: Neutral or mixed
Social: Positive
Economic: Positive

Generally, there are no environmental side effects from classical biological control, if the pre-release host range tests and risk assessment were comprehensive and completed appropriately. If they are not done appropriately, then unintended effects on non-target organisms would constitute a negative side effect. In the case of the Asiatic tearthumb weevil the host specificity tests for its release in North America were conclusive: of all of the cultivated and wild plant species tested (49) in lab and open-field trials, only *P. perfoliata* seemed to fall within the physiological host range of *R. latipes* and findings suggest that *R. latipes* has a narrow host range and poses minimal potential risks to non-target plants (Colpetzer *et al.*, 2004a).A precautionary approach should be applied in new geographical contexts, also considering the most recent requirements expressed by the scientific community (for example Schaffner *et al.*, 2018; Havens *et al.*, 2019). The social side-effects are also generally positive when the public realizes that use of classical biological control for weeds can help to minimize the use of herbicides. In addition, reduced use of herbicides and/or mowing or other control measure can result in an economic benefit from classical biological control.

ACCEPTABILITY TO STAKEHOLDERS

Neutral or mixed.

Public perception of classical biological is mixed; it can be positive due to the use of natural enemies instead of pesticides; or negative due to historical instances of non-target effects.

ADDITIONAL COST INFORMATION

If biological control continues to provide long term management of a weed the cost savings from no longer using other management techniques that need to be repeated annually can be significant (Hough-Goldstein *et al.*, 2015).

LEVEL OF CONFIDENCE*

Well established.

Classical biological control of *P. perfoliata* in the Northeast U.S.A. has been used since 2004. There are many studies documenting successful establishment and dispersal of *R. latipes*, and significant impacts to *P. perfoliata* (for example Hough-Goldstein *et al.*, 2009, 2011).

* See Appendix

Mechanical control.

MEASURE DESCRIPTION

There are many effective mechanical control methods for Asiatic tearthumb weed. According to best practice guidance by Travis and Kiviat (2016) small patches can be controlled by hand-pulling (see *eradication* section above), but larger areas can be mown or cut with a scythe or strimmer, which is effective if accomplished prior to fruit production. They recommend that Asiatic tearthumb should be cut close to ground level, or it will regrow from the cut stem and a second cutting in late summer may be needed. Pulling or cutting efforts will need to be repeated until the seedbank is exhausted, which can take up to 6 years. Mechanical control can be difficult for the vines that climb trees (NPS, 2009). All plant material needs to be removed and disposed of to prevent re-rooting, and if any fruits are present on pulled or cut plants they need to be bagged and left in the sun for several weeks before landfilling, or be piled in a frequently-mowed area that can be easily monitored for regrowth (Travis and Kiviat, 2016).

Mechanical methods may be ineffective if not repeated, as in the removal process seeds may be left behind (Oliver, 1996). For this reason, all physical and mechanical methods are most successful when conducted before seed set (Stone, 2010). Moreover the soil seed bank takes several years (up to 6) to lose its viability, so new seedlings need to be removed.

SCALE OF APPLICATION

This is best applied at a small scale such as an individual property.

EFFECTIVENESS OF MEASURE

Effective.

Management guidelines (Travis and Kiviat, 2016) recommend mechanical control for controlling small patches of Asiatic tearthumb.

EFFORT REQUIRED

Removal of a population of Asiatic tearthumb by mechanical means may take up to 6 years due to longevity of the seed bank.

RESOURCES REQUIRED

Mower, scythe or strimmer. Gloves and other protective clothing. Access to transport and disposal facilities

SIDE EFFECTS

Environmental: Neutral or mixed
Social: Neutral or mixed
Economic: Neutral or mixed

One potential negative side effect of mechanical removal of a Asiatic tearthumb population is opening up of space in an area for the invasion of additional invasive species. This could have environmental effects (negative impact on native species), social effects (negative aesthetics of invasive species), and economic effects (cost of further control for new invasive species). Based on the ecology of the plant and on findings available in literature (even if they come from the application of other kinds of management measures as those cited by Hough-Goldstein *et al.*, 2012), this negative side effect should be prevented or reduced by combining mechanical control and plant cover restoration (seeding/planting perennials or trees, dense canopy maintenance; Travis and Kiviat, 2016). This kind of integrated management would require further research before application, but it is known that restoration practices could be useful to delay or prevent re-invasion after control (Byun *et al.*, 2018). Positive effects are primarily due to cost savings over herbicides.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

This measure is likely to be acceptable to stakeholders as it will have minimal negative impacts.

ADDITIONAL COST INFORMATION

No information available.

LEVEL OF CONFIDENCE*

Established but incomplete.

This measure is likely to be acceptable to stakeholders as it will have minimal negative impacts.

* See Appendix

Herbicides.

MEASURE DESCRIPTION

There are several active ingredients and herbicides that have proven effective in controlling larger infestations of Asiatic tearthumb. These include the herbicides Arsenal (imazapyr), Oust (sulfometuron methyl), Roundup (glyphosate), and Velpar (hexazinone) (McCormick, 2013).

Large infestations should be treated with a pre-emergent herbicide in the early spring, just before the seeds will begin to germinate. Effective pre-emergent herbicides include Pendulum Aquacap (pendimethalin) and Plateau (imazapic). However, pre-emergent herbicides may be less suitable for application in natural areas due to non-target impacts, as opposed to agricultural or forestry areas. Then a post-emergent herbicide should be applied in late spring to early summer to control those plants missed or not killed by the pre-emergent application. Triclopyr and Glyphosate are both effective at controlling post-emergent Asiatic tearthumb (Rathfon, 2016).

EU/national/local legislation on the use of plant protection products and biocides need to be respected when applying this measure.

SCALE OF APPLICATION

Herbicide applications will be applied on a small scale, such as an individual property.

EFFECTIVENESS OF MEASURE

Effective.

The use of herbicides is indicated as an efficient measure by several protocols in the USA even if precise data about plant suppression seem not to be available in literature. Lake *et al.,* (2014) tested herbicides efficacy in an integrated management protocol which combined pre- emergence herbicide and perennials planting (in sites already colonized by *R. latipes*). The authors declared that in their study, the one-time pre-emergent application largely prevented recruitment of both native and non-native seeds from the seed bank at the beginning of the trial, but enabled the establishment of planted perennials with reduced competition.

EFFORT REQUIRED

Lake *et al.*, (2014) showed that one-time application of pre-emergence herbicide could be enough to provide control of *P. perfoliata* at least during the following three years (test duration). Other protocols call for pre- and post-emergence herbicide application (herbicide application twice a year) (Glover, 2013).

RESOURCES REQUIRED

Herbicide application requires trained and qualified staff, and adequate equipment to achieve proper application of the herbicide, preventing or at least minimizing risks to human health and biodiversity. Surfactants are recommended in order to improve herbicide effectiveness by increasing spray's adherence to the leaf surface (Hough-Goldstein *et al.*, 2015).

SIDE EFFECTS

Environmental: Negative
Social: Neutral or mixed
Economic: Neutral or mixed

According to Rathfon (2016) the pre-emergent herbicides, if applied at the proper rates and time should not harm all plants, particularly perennials that break dormancy later in the spring or annuals that germinate later on. Triclopyr is a broadleaf-specific herbicide, so will not harm grasses and sedges, however Glyphosate is a broad-spectrum herbicide and will damage all classes of plants. Several herbicides can have direct or indirect negative impact on fauna (for example insects; Saska *et al.*, 2016).

ACCEPTABILITY TO STAKEHOLDERS

Neutral or mixed.

The mixed acceptability of this option by stakeholders results from public concerns about the use and safety of herbicides balanced with their views of the negative impacts of *P. perfoliata*. Prioritizing use of other measures, and integrating herbicides with other measures (integrated management protocols) has the potential to reduce the need for extensive herbicide use.

ADDITIONAL COST INFORMATION

No information available.

LEVEL OF CONFIDENCE*

Well established.

There are comprehensive Cooperative Extension fact sheets and guidelines from the US for herbicide use against *P. perfoliata* (McCormick, 2013 and Rathfon, 2016).

* See Appendix

Integrated control.

MEASURE DESCRIPTION

The integration of seeding with native plants and selective herbicide use can have an additive effect with biological control to lower *P. perfoliata* density (Cutting and Hough-Goldstein, 2013). The objective of this measure is to integrate planting of native species with the use of weevils to suppress *P. perfoliata* and restore the native plant community, preventing the colonization by other alien plants. Planting with natives in *R. latipes* release sites causes enhanced competition and improves the effectiveness of biological control.

Experimental treatments have shown that the use of selective herbicides can be integrated along with restoration planting and biological control (Lake *et al.*, 2011). It is important to underline that these treatments have been undertaken in sites where the control agent was already present and established, and only new releases have been done to increase the population number (Lake *et al.*, 2011, 2014). The experimental integration of all three measures suppressed Asiatic tearthumb, prevented invasion by Japanese stilt grass and increased native plant abundance (Lake and Minteer, 2018).

SCALE OF APPLICATION

The only information on this measure is from two integrated weed management experiments associated with biological control with weevils, and both were conducted in Pennsylvania (Lake *et al.*, 2011, 2014). These experiments were conducted in small experimental plots (6.1 x 6.1m in one case, and 2 x 2m in the other).

EFFECTIVENESS OF MEASURE

Effective.

This measure has been shown to be effective, but only under experimental conditions. In one study that integrated biological control, herbicide use and native plantings (Lake *et al.,* 2014) after 2 years, native plant cover differed significantly across treatment methods, it was greater than 80% in the plots with plantings and pre-emergent herbicide, but less than 30% in the planting treatments without herbicide. In another study, the addition of a pre-emergent herbicide improved the establishment of the perennial vegetation (Lake *et al.*, 2011). Additional studies of the integration of these management techniques are needed.

EFFORT REQUIRED

There is no information about the period of time over which the measure needs to be applied to have results outside of the experimental plots and test durance.

RESOURCES REQUIRED

See biological control and herbicide sections. In addition native plants for seeding will be required.

SIDE EFFECTS

Environmental: Neutral or mixed
Social: Positive
Economic: Positive

The side effects of biological control and herbicides are discussed above. Social effects would generally be considered positive due to utilizing seeding of native plants and biological control to initiate a long term management program. The social and economic effects could be significant if the integration of the three techniques leads to improved control, while preventing establishment of additional invasive weeds (Lake and Minteer, 2018).

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

Public perception of an integrated strategy may be positive, but there is no information on this.

ADDITIONAL COST INFORMATION

There are no implementation cost studies available.

LEVEL OF CONFIDENCE*

Established but incomplete.

The two studies mentioned above establish the effectiveness of the measure. Integrated weed management often offers positive impacts on alien plant management, but additional studies are necessary to investigate its ecological and economic benefits (Lake and Minteer, 2018).

* See Appendix

Grazing with livestock.

MEASURE DESCRIPTION

Grazing with livestock is being used to control a number of invasive weed species. Intensive rotational target grazing of sheep (IRTG) for management of *P. perfoliata* resulted in a decrease in percent cover and inflorescence and an increase in species richness (Girard, 2011). Over the course of another study with sheep grazing (43 days), *P. perfoliata* percent cover in the grazed areas decreased by 75%, while it increased by 193% in the ungrazed areas (Girard-Cartier and Kleppel, 2015). Also mean inflorescence was significantly lower in grazed areas than in ungrazed areas, and species richness was significantly greater in grazed enclosures (Girard-Cartier and Kleppel, 2015).

SCALE OF APPLICATION

The scale of the studies cited here was small; each treatment paddock was $200m^2$.

EFFECTIVENESS OF MEASURE

Effective.

Effectiveness has only been demonstrated in two studies summarized above, and requires additional field trials to demonstrate long-term effectiveness. Girard (2011) suggested that the effectiveness of grazing would increase in integrated weed management plans: grazing (in IRTCG), when used in conjunction with other management techniques may be even more effective at managing *P. perfoliata* than when used alone.

EFFORT REQUIRED

The measure will have to be repeated until seed bank has been depleted, which can take up to 6 years.

RESOURCES REQUIRED

Costs associated with permitting and testing of control agents (such as, livestock) are relatively trivial compared with insect or microbial bio-control or with herbicide use. Infrastructure (fencing) and maintenance (food supplements, medicine) costs vary with livestock species and breeds, but tend to be lower than for other invasive species control methods.

Persicaria perfoliata © *mefisher. CC0 1.0.*

SIDE EFFECTS

Environmental: Neutral or mixed
Social: Neutral or mixed
Economic: Neutral or mixed

Grazing by livestock should not have many negative side effects, if grazing pressure is adequately calibrated to the application scale. Overgrazing could be detrimental for native vegetation and ecologic equilibrium and it may be not adequate to all types of landscapes.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

Grazing farm animals is generally an acceptable measure for control in many locations, though it will not be appropriate for all areas.

ADDITIONAL COST INFORMATION

No information available.

LEVEL OF CONFIDENCE*

Unresolved.

These are the only two studies conducted on grazing. More research is needed.

* See Appendix

Bibliography

Berg, S.H., Hough-Goldstein, J., Lake, E.C. and D'Amico, V. 2015. Asiatic tearthumb Weed (*Persicaria perfoliata*) and Weevil (*Rhinoncomimus latipes*) Response to Varying Moisture and Temperature Conditions. Biological Control. 83:68-74.

Berner, D.K., and Cavin, C.A. 2012. First Report of Anthracnose of Asiatic tearthumb (*Persicaria perfoliata*) Caused by *Colletotrichum cf. gloeosporioides* in Turkey. Disease Notes. 96(10):1578.

Byun, C., de Blois, S., andBrisson, J. 2018. Management of invasive plants through ecological resistance. *Biological invasions*, *20*(1), 13-27.

Brundi, G., Aksoy, N., Brunel, S., Elias, P. and Fried, G. 2011. Rapid surveys for inventorying alien plants in the Black Sea region of Turkey. *EPPO Bulletin*, 41(2)

Colpetzer, K., Hough-Goldstein, J., Ding, J. and Fu, W. 2004a. Host Specificity of the Asian Weevil, *Rhinoncomimus latipes* Korotyaev (Coleoptera: Curlionidae), a Potential Biological Control Agent of Asiatic tearthumb Weed, *Polygonumperfoliatum* L. (Polygonales: Polygonaceae). Biological Control. 30:511-522.

Colpetzer, K., Hough-Goldstein, J., Harkins, K.R. and Smith, M.T. 2004b. Feeding and Oviposition Behavior of *Rhinoncomimus latipes* Korotyaev (Coleoptera: Curculionidae) and its Predicted Effectiveness as a Biological Control Agent for *Polygonum perfoliatum* L. (Polygonales: Polygonaceae). Environ. Entomol. 33(4):990-996.

CABI. 2019. Invasive Species Compendium. Datasheet: *Persicaria perfoliata* (Asiatic tearthumb weed). https://www.cabi.org/isc/datasheet/109155

Cutting, K.J. and Hough-Goldstein, J. 2013. Integration of Biological Control and Native Seeding to Restore Invaded Plant Communities. Restoration Ecology. 21(5):648-655.

Ding, J. 2019. Datasheet: *Persicaria perfoliata* (Asiatic tearthumb weed). Invasive Species Compendium. CAB International.[Accessed 20 April 2019].

Ding, J., Fu, W., Reardon, R., Wu, Y., and Zhang, G. 2004. Exploratory Survey in China for Potential Insect Biocontrol Agents of Asiatic tearthumb Weed, *Polygonum perfoliatum* L., in Eastern USA. Biological Control. 30:487-495.

Ding, J., Reardon, R., Wu, Y., Zheng, H. and Fu, W. 2006. Biological Control of Invasive Plants through Collaboration between China and the United States of America: a perspective. Biological Invasions. 8:1439-1450.

EC. 2000. Council Directive 2000/29/EC of 8 May 2000 on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community. Official Journal L169.

EC. 2019. Commission Implementing Directive (EU) 2019/523 of 21 March 2019 amending Annexes I to V to Council Directive 2000/29/EC on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019L0523

EPPO. Undated. PRA Pest Risk Analysis for *Polygonum perfoliatum*. Guidelines on Pest Risk Analysis. European and Mediterranean Plant Protection Organisation. 2006-09 Version no. 2.

Farooq, S., Tad, S., Onen, H., Gunai, H., Caldiran, U., and Ozaslan, C. 2017. Range Expansion Potential of Two Co-Occurring Invasive Vines to Marginal Habitats in Turkey. ActaOecologica. 84:23-33.

Field Release of *Rhinoncomimus latipes* (Coleoptera: Curculionidae), a Weevil for Biological Control of Asiatic tearthumb Weed (*Polygonum perfoliatum*) in the Continental United States. 2004. Final Environmental Assessment. Dr. Robert Flanders, Pest Permit Evaluation Branch, Plant Protection and Quarantine, USDA.

Fredericks, J.G. III. 2001. A Survey of Insect Herbivores Associated with *Polygonum perfoliatum* L. (Asiatic tearthumb weed) and comparisons of leaf damage and insect diversity between recently established and mature populations. M.S. thesis. University of Delaware, Newark, DE.

Frye, M.J., Lake, E. and Hough-Goldstein, J. 2010. Field Host-Specificity of the Asiatic tearthumb Weevil, *Rhinoncomimus latipes* Korotyaev (Coleoptera: Curculionidae). Biological Control. 55:234-240.

Girard, C.B. and Kleppel, G.S. 2011. Intensive Rotational Grazing of Romney Sheep as a Control for the Spread of *Persicaria perfoliata*. Section III: 1-22 *In* D.J. Yozzo, S.H. Fernald and H. Andreyko (eds.), Final Reports of the Tibor T. Polgar Fellowship Program, 2009. Hudson River Foundation.

Girard-Cartier, C.B., Keppel, G.S. 2015. Grazing as a Control for the Spread of Asiatic tearthumb (*Persicaria perfoliata*) and the Restoration of Biodiversity in Plant Communities in a Lower New York State Parkland.

Global Invasive Species Database. 2019. Species profile: *Persicaria perfoliata*. Downloaded from http://www.iucngisd.org/gisd/species.php?sc=582 on 12-07-2019.

Glover, A. 2013. Invasive Plant Species ManagementQuick Sheet 7: Asiatic tearthumb (*Persicaria perfoliata*). Penn State Wildland Weed Management College of Agricultural Sciences. https://plantscience.psu.edu/research/projects/wildland-weed-management/publications/invasive-species-quicksheets/Asiatic tearthumb

Guo, W., Zhang, J., Li, X., and Ding, J. 2011. Increased Reproductive Capacity and Physical Defense but Decreased Tannin Content in an Invasive Plant. Insect Science. 18:521-532

Havens, K., Jolls, C. L., Knight, T. M., and Vitt, P. 2019. Risks and Rewards: Assessing the Effectiveness and Safety of Classical Invasive Plant Biocontrol by Arthropods. *BioScience*, 69(4), 247-258.

Hough-Goldstein, J.A. 2008. Assessing Herbivore Impact on a Highly Plastic Annual Vine. XII International Symposium on Biological Control of Weeds. pp. 283-286.

Hough-Goldstein, J.A. and S.J. LaCoss. 2012. Interactive Effects of Light Environment and Herbivory on Growth and Productivity of an Invasive Vine, *Persicaria perfoliata*. Arthropod-Plant Interactions 6:103-112.

Hough-Goldstein, J. and Lake, E. 2008. New Developments in Biological Control of Asiatic tearthumb Weed. North. J. Appl. For. 25(3):164-165.

Hough-Goldstein, J., Lake, E., D'Amico, V. and Bert, S.H. 2012. Preferential Edge Habitat Colonization by a Specialist Weevil, *Rhinoncomimus latipes* (Coleoptera: Curculionidae). Environ. Entomol. 41(6):1466-1473.

Hough-Goldstein, J., Lake, E. and Reardon, R. 2011. Status of an Ongoing Biological Control Program for the Invasive Vine, *Persicaria perfoliata* in Eastern North America. DOI 10.1007/s10526-011-9417-z.

Hough-Goldstein, J., Lake, E., Reardon, R. and Wu, Y. 2015. Biology and Biological Control of Asiatic tearthumb Weed. U.S. Forest Service, Forest Health Technology Enterprise Team, Morgantown, WV.

Hough-Goldstein, J., Lake, E. C., Shropshire, K. J., Moore, R. A., and D'Amico, V. 2016. Laboratory and field-based temperature-dependent development of a monophagous weevil: implications for integrated weed management. *Biological control*, *92*, 120-127.

Hough-Goldstein, J., Mayer, M.A., Hudson, W., Robbins, G., Morrison, P., and Reardon, R. 2009. Monitored Releases of *Rhinoncomimus latipes* (Coleoptera: Curculionidae). Biological Control. 51:450-457.

Hough-Goldstein, J., Schiff, M., Lake, E. and Butterworth, B. 2008. Impact of the Biological Control Agent *Rhinoncomimus latipes* (Coleoptera: Curculionidae) on Asiatic tearthumb Weed, *Persicaria perfoliata* in Field Cages. Biological Control. 46:417-423, Hough-Goldstein, J., Stout, A.R., and Schoenstein, J.A. 2014. Fitness and Field Performance of a Mass-Reared Biological Control Agent, *Rhinoncomimus latipes* (Coleoptera: Curculionidae). Environ. Entomol. 43(4):923-931.

Hudson, W., Diercks, A., Robbins, G., Ou, C., Strubel, R. and Lovero, A. 2008. Annual Report: *Rhinoncomimus latipes* (Coleoptera: Curculionidae) as a Biological Control Agent for Asiatic tearthumb (*Persicariaperfoliata*) in New Jersey. Philp Alampi Beneficial Insect Laboratory, Division of Plant Industry, New Jersey Department of Agriculture.

Hudson, W., Robbins, G., Detweiler, C., Lovero, A., Mayer, M., and Beetle, J. 2017. Annual Report: *Rinoncomimus latipes* (Coleoptera: Curculionidae) as a Biological Control Agent for Asiatic tearthumb (*Persicaria perfoliata*) in New Jersey. Philip Alampi Beneficial Insect Laboratory, Division of Plant Industry, New Jersey Department of Agriculture.

Hyatt, L.A., Araki, S. 2006. Comparative Population Dynamics of an Invading Species in its Native and Novel Ranges. Biological Invasions. 8:261-275.

IPPC. 2017. International Standards for Phytosanitary Measures, ISPM 40. International movement of growing media in association with plants for planting. International Plant Protection Convention. FAO, Rome. https://www.ippc.int/static/media/files/publication/en/2017/05/ISPM_40_2017_En_2017-05-15_oI08UDw.pdf

IPPC. 2017. International Standards for Phytosanitary Measures, ISPM 41. International movement of used vehicles, machinery and equipment. International Plant Protection Convention. FAO, Rome. https://www.ippc.int/static/media/files/publication/en/2017/05/ISPM_41_2017_En_2017-05-15.pdf

Kikodze, D., Memiadze, N., Kharazishvili, D., Manvelidze, Z. and Mueller-Schaerer, H. 2010. The Alien Flora of Georgia. 2nd ed. Swiss National Science Foundation, Swiss Agency for Development and Cooperation and SCOPES (project number IB73A0–110830).

Kumar, V. and DiTommaso, A. 2005. Asiatic tearthumb (*Polygonum perfoliatum*): An Increasingly Problematic Invasive Species. Weed Technology 19(4):1071-1077.

Lake, E.C., Hough-Goldstein, J. and D'Amico, V. 2014. Integrating Management Techniques to Restore Sites Invaded by Asiatic tearthumb Weed, *Persicaria perfoliata,* Restoration Ecology, 22(2), 127-133.

Lake, E.C., Hough-Goldstein, E., Shropshire, K.J. and D'Amico, V. 2011. Establishment and Dispersal of the Biological Control Weevil *Rhinoncomimus latipes* on Asiatic tearthumb Weed, *Persicaria perfoliata*. Biological Control. 58:294-301.

Lake, E., Cutting, K. and Hough-Goldstein, J. 2011. Integrating Biological Control and Native Plantings to Restore Sites Invaded by Asiatic tearthumb Weed, *Persicaria perfoliata*, in the Mid-Atlantic USA. XIII International Symposium on Biological Control of Weeds. Session 6. pp. 254-261.

Lake, E. and Minteer, C.R. 2018. A Review of the Integration of Classical Biological Control with other Techniques to Manage Invasive Weeds in Natural Areas and Rangelands. BioControl. 63:71-86.

Ledoux, C.B. and Martin, D.K. 2012. Proposed BMPs for invasive plant mitigation during timber harvesting operations. USDA For Serv Gen Tech Rep NRS-118. 16p.

McCormick, L.H. 2013. Asiatic tearthumb. Penn State Extension.

Miller, W.R. and Connolly, B.A. 2018. A New Record of Invasive Asiatic tearthumb Vine, *Persicaria perfoliata* (Polygonaceae) in New Hampshire. Rhodora. 120(982):179-180.

Miura, K., Iida, H., Imai, K., Lyon, S., Reardon, R., and Fujisaki, K. 2008. Herbivorous Insect Fauna of Asiatic tearthumb Weed, *Persicaria perfoliata* (Polygonaceae), in Japan. The Florida Entomologist. 91(2):319-323.

Mountain, W.L. 1989. Asiatic tearthumb (*Polygonumperfoliatum* L.) Update-Distribution, Biology and Control Suggestions. Regulatory Horticulture Weed Circular No. 15(2). Pennsylvania Dept. of Agriculture. Bureau of Plant Industry.

Myers, J.A., Vellend, M., Gardescu, S. and Marks, P.L. 2004. Seed Dispersal by white-tailed deer: implications for long-distance dispersal, invasion, and migration of plants in Eastern North America. Oecologia 139:35-44.

NPS, 2009. Weeds gone wild, alien plant invaders of natural areas., Washington, USA; National Park Service, US Dept. of the Interior, http://www.nps.gov/plants/alien/

Obwi, J.A. 1965. Flora of Japan. Smithsonian Institute, Washington, D.C.

Okay, J.A.G. 1999. Asiatic tearthumb Weed *(Polygonumperfoliatum*). DCNR Invasive Exotic Plant Tutorial for Natural Lands Managers. Information taken in part for the Plant Conservation Alliance, Alien Plant Working Group Weeds Gone Wild website http://www.nps.gov/plants/alien/factmain.htm. (last update April 23, 1999).

Okay, J.A., Hough-Goldstein, J. and Swearingen, J.M. 2007. Fact Sheet: Asiatic tearthumb Weed. Plant Conservation Alliance's Alien Plant Working Group. http://www.nps.gov/plants/alien/.

Oliver, J.D. 1996. Asiatic tearthumb Weed (*Polygonum perfoliatum*), an Invasive Vine in Natural and Disturbed Sites. Castanea 61(3):244-251.

Oliver, J.D. and Cole, N.C. 1994. *Polygonum perfoliatum* L. (Polygonaceae), the Asiatic tearthumb Weed. Botany Circular No. 29. Fla. Dept. Agric. and Consumer Services. Division of Plant Industry.

O'Rourke, E. and Lysaght, L. 2014. Risk Assessment of *Persicaria perfoliata*. Inland Fisheries Ireland and the National Biodiversity Data Centre. http://nonnativespecies.ie/wp-content/uploads/2014/03/Persicaria-perfoliata-Asiatic tearthumb-Weed.pdf

Park, Y-Y., Gururajan, S., Thistle, H., Chandran, R. and Reardon, R. 2018. Aerial release of *Rhinoncomimus latipes* (Coleoptera: Curculionidae) to control *Persicaria perfoliata* (Polygonaceae) using an unmanned aerial system. Pest Management Science, 74: 141-148.

Paynter, Q. Fowler, S.V., Hayes, L., and Hill, R.L. 2014. Factors Affecting the Cost of Weed Biocontrol Programs in New Zealand. Biological Control. 80:119-127.

Poindexter, D.B. 2010. *Persicaria perfoliata* (Polygonaceae) Reaches North Carolina. Phytoneuron 30:1-9.

Simpson, A., Jarnevich, C., Madsen, J., Westbrooks, R., Fournier, C., Mehrhoff, L., Browne, M., Graham, J. and Sellers, E. 2009. Invasive Species Information Networks: Collaboration at Multiple Scales for Prevention, Early Detection, and Rapid Response to Invasive Alien Species. Biodiversity. 1-:2-3, 5-13, DOI: 10.1080/4888386.2009.9712839.

Price, D.L., J. Hough-Goldstein and Smith, M.T. 2003. Biology, rearing, and preliminary evaluation of host range of two potential biological control agents for Asiatic tearthumb weed, *Polygonum perfoliatum* L. Environmental Entomology 32:229-236.

Rathfon, R. 2016. Asiatic tearthumb Vine. Invasive Plant Series. Purdue Extension. Southern Indiana Cooperative Invasives Management FNR-481-W.

Rathfon, R. 2016. Invasive Plant Series Fact Sheets: Asiatic tearthumb Vine *Persicaria perfoliata* (L.) H. Gross. Southern Indiana Cooperative Invasives Management. https://www.extension.purdue.edu/extmedia/FNR/FNR-481-W.pdf

Saska, P., Skuhrovec, J., Lukáš, J., Chi, H., Tuan, S. J., andHoněk, A. 2016. Treatment by glyphosate-based herbicide alters life history parameters of the rose-grain aphid *Metopolophium dirhodum. Scientific reports*, *6*, 27801

Schaffner, U., Smith, L., and Cristofaro, M. 2018. A review of open-field host range testing to evaluate non-target use by herbivorous biological control candidates. *Biocontrol*, *63*(3), 405-416

Simpson, A., Jarnevich, C., Madsen, J., Westbrooks, R., Fournier, C., Mehrhoff, L., Browne, M., Graham, J. and Sellers, E. 2009. Invasive Species Information Networks: Collaboration at Multiple Scales for Prevention, Early Detection, and Rapid Response to Invasive Alien Species. Biodiversity 10:2-3, 5-13.

Smith, J.R. and Hough-Goldstein, J. 2013. Phototaxis, Host Cues, and Host-Plant Finding in a Monaphagous Weevil, *Rhinoncomimus latipes*. Journal of Insect Behavior. 26:109-119.

Smith, J.R. and Hough-Goldstein, J. 2014. Impact of Herbivory on Asiatic tearthumb Weed (*Persicaria perfoliata*) seed production and viability. Biological Control. 76:60-64.

Smith, J.R., Hough-Goldstein, J. and Lake, E.C. 2014. Variable Seed Viability of MAM Weed (Devil's Tearthumb, *Persicaria perfoliata*). Invasive Plant Science and Management. 7:107-112.

Stahl, C. 2002. Introduced Species Summary Project: Asiatic tearthumb weed, Devil's Tail Tearthumb (*Polygonum perfoliatum*) Columbia University. http://www.columbia.edu/itc/cerc/danoff-burg/invasion_bio/inv_spp_summ/Polygonum_perfoliatum.htm.

Stone, K.R. 2010. *Polygonum perfoliatum*In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Available: https://www.fs.fed.us/database/feis/plants/vine/polpef/all.html [Accessed 20 April 2019].

Travis, K.B. and Kiviat, E. 2016. Best Management Practices for Priority Invasive Plants in the Lower Hudson Valley. Report to the Lower Hudson Partnership for Regional Invasive Species Management. Hudsonia Ltd. Annandale, NY. https://www.lhprism.org/system/files/documents/Best%20Management%20Practices%20for%20Priority%20Invasive%20Plants%20in%20the%20Lower%20Hudson%20Valley.pdf

USDA Forest Service. Undated. Asiatic tearthumb weed Biological Control. Forest Health Technology Enterprise Team. https://www.fs.fed.us/foresthealth/technology/pdfs/FS_mam.pdf

Wheeler, A.J. and Mengel, S.A. 1984. Phytophagous Insect Fauna of *Polygonum perfoliatum*, an Asiatic Weed Recently Introduced in Pennsylvania. Annals of the Entomological Society of America 77:197-202.

Wilson, C.E., Castro, K.L., Thurston, G.B. and Sissons, A. 2016. Pathway Risk Analysis of Weed Seeds in Imported Grain: A Canadian Perspective. In: Daehler, C.c., van Kleuren, M., Pysek, P. and Richardson, D.M. (Eds.). Proceedings of 13th International EMAPi Conference, Waikoloa, Hawaii. NeoBiota. 30:49-74.

Wilton, A.D., Schönberger, I., Boardman, K.F., Breitwieser, I., Cochrane, M., Dawson, M.I., de Lange, P.J., de Pauw, B., Fife, A.J., Ford, K.A., Gibb, E.S., Glenny, D.S., Heenan, P.B., Korver, M.A., Novis, P.M., Redmond, D.N., Smissen, R.D., and Tawiri, K. 2016. Checklist of the New Zealand Flora – Seed Plants. Lincoln, Manaaki Whenua-Landcare Research. http://dx.doi.org/10.7931/P1PP42

Wu, Y., Reardon, R.C. and Ding, J. 2002. Asiatic tearthumb Weed. In: Van Driesche, R., Lyon, S. Blossey, B., Hoddle, M. and Reardon, R. (Eds.). Biological Control of Invasive Plants in the Eastern United States. USDA Forest Service Publication. FHTET-2002-04, pp. 331-341.

Appendix

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

- **Well established:** comprehensive meta-analysis or other synthesis or multiple independent studies that agree. *Note:* A statistical method for combining results from different studies which aims to identify patterns among study results, sources of disagreement among those results, or other relationships that may come to light in the context of multiple studies.
- **Established but incomplete:** general agreement although only a limited number of studies exist but no comprehensive synthesis and/or the studies that exist imprecisely address the question.
- **Unresolved:** multiple independent studies exist but conclusions do not agree.
- **Inconclusive:** limited evidence, recognising major knowledge gaps

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