Lysichiton americanus *is found in swamps and wet woods, along streams and in other wet areas. © Tim Adriaens, INBO*

The management of American skunk cabbage (*Lysichiton americanus*)

Measures and associated costs

Scientific name(s)	*Lysichiton americanus* Hultén & H. St. John
Common names (in English)	American skunk cabbage
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Common names

BG	Жълт миризлив змиярник
HR	Američki lisihiton
CZ	Lysichiton americký
DA	Gul kæmpekalla
NL	Moeraslantaarn
EN	American skunk cabbage
ET	Ameerika kevadvõhk
FI	Keltamajavankaali
FR	Faux arum
DE	Gelbe Scheincalla
EL	–
HU	Sárga lápbuzogány
IE	Geathar buí
IT	Lysichiton americano
LV	Amerikas lizihitons
LT	Amerikinis dvokūnas
MT	–
PL	Tulejnik amerykański
PT	Lanterna-do-pântano
RO	Felinar de apă
SK	–
SL	Ameriški lizihiton
ES	Aro de agua
SV	Gul skunkkalla

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

L. americanus is a robust perennial herbaceous plant native to western North America. It forms large clumps and one adult plant may cover 1 m^2 ground. *L. americanus* can be a geophyte or a hydrophyte, with a fleshy rhizome (up to 30 cm long and with a diameter of 2.5-5 cm). Growth is slow but *L. americanus* can build up old (more than 80 years) and dense populations. Inflorescences appear between March and May, emerging and flourishing before the leaves come out. Seeds mature in its native area of distribution from June to July, and in Europe in July or early August.

L. americanus first was introduced into the UK at the beginning of the 20th century as a garden ornamental (Clement and Foster, 1994). The species has also been introduced in other EU Member States (EPPO, 2009) and has since been sold in many European countries. It grows in marshes, fens, marshy woods, bog woodlands, along streams and riverbanks, lakesides, ponds, in seepage areas, in bogs, wet meadows and other wet areas at low to middle elevations. *L. americanus* is a nitrophilic species, favoured by nutrient-rich wetlands. It spreads readily through seed dispersal and large underground rhizomes. It may also be capable of establishing from root fragments, meaning that care is needed to collect all plant matter if digging it up. The main risk is if *L. americanus* establishes in wet woodlands where it readily forms large colonies, displacing the native species, and spreading along waterways.

As the species is listed as of Union concern, its trade, cultivation and release in the environment is now banned. However, the plant is already present in many garden ponds so a targeted engagement with public who cultivate individuals in garden ponds would support the implementation of the EU IAS Regulation to prevent further intentional introductions. The aim would be to raise awareness and provide guidance on how to remove *L. americanus* from their gardens in order to prevent new establishment of the plant in the wild. In terms of unintentional introductions, the seeds or fragments of the species could be a contaminant of soil (as a commodity itself), and as a contaminant of soil attached to vehicles and machinery, imported into the EU or into EU Member States from other EU Member States. To address these pathways, restrictions on the import of soil, and implementation of import/export standards for cleaning vehicles and machinery would be needed, however these measures are unlikely to be cost-effective. It is also important to implement biosecurity measures in infested sites such as cleaning vehicles and equipment used in these sites as well as proper disposal of waste of the excavated plants in order to prevent secondary spread.

Only a limited number of methods have been tested for effectively managing *L. americanus*. So far, it has been successfully removed by manual control through digging or by spraying herbicides. Manual control of *L. americanus* using a sharp spade to dug out the plants have been more widely used and seems more efficient than using herbicides that lead to mixed results (although considered as efficient if applied in optimal conditions) and that is negatively perceived due to side-effects on health and environment. Pending funding for eradication, it is recommended to limit the spread of the plant, and this can be achieved through removal of the flower heads before they go to seed. Due to a persistent seed bank (up to 8 years seed longevity), any treatment requires a long-term commitment (ranging between 5 to 15 years) to exhaust the seed bank and fully eradicate this species.

Currently, none of the following methods have been tested in enough depth to provide evidence that they would be effective at controlling American skunk cabbage: shading through promotion of native plants, biological control, flame treatments, tarpaulin, hydrogen peroxide, liquid nitrogen.

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 keeping, importing (pre-border measure), selling, breeding and growing as required under Article 7 of the IAS Regulation, targeting intentional introduction of plants and propagules of *L. americanus*.

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 measures and inspections related to movement of soil and vehicles/machinery.

MEASURE DESCRIPTION

According to EPPO (2006), it is possible that "fragments of stem or rhizome of *Lysichiton americanus* could be spread by machines and vehicles used for sylviculture, as in construction of lanes, or tree cutting and transportation". However, the EPPO Expert Working Group that performed the Pest Risk Analysis on *L. americanus* considered that "spread by fragmentation of rhizomes through machines and vehicles or other human activities is unlikely to happen due to the depth of the rhizomes of the plant, and the few management measures in the habitats where it occurs", such as wet or waterlogged forests (EPPO, 2009). If vegetative spread is unlikely, movement of soil may still spread seeds of the plant (EPPO, 2009).

Phytosanitary inspections and associated measures developed for other species of Union concern (such as *Impatiens glandulifera*, *Parthenium hysterophorus*) which can spread with the same type of commodities (especially soil originating from river banks) can act to prevent the unintentional entry of *L. americanus* into specific countries/regions.

The importation of soil into the EU (but not between EU Member States) 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). The Plant Health Directive prohibits the import of soil [and growing media] as such from most but not all third countries[1]. These conditions have recently been amended by Implementing Directive (EU) 2019/523 (EC 2019) and will ban soil imports from all third countries, apart from Switzerland, and will need to be applied by Member States from 1 September 2019.

To prevent the import and movement of contaminated soil with *L. americanus* seeds into and between EU Member States, individual Member States could also ban the import of soil from other EU Member States.

In terms of contaminated soil attached to machinery or vehicles, import standards should follow ISPM Standard, no. 41 (IPPC, 2017) on 'International movement of used vehicles, machinery and equipment'. This focuses on reducing the risks of transporting contaminants (soil, seeds, plant debris, pests) associated with the international movement (either traded or for operational relocation) of vehicles, machinery and equipment (hereafter VME) that may have been used in agriculture, forestry, as well as for construction, industrial purposes, mining and waste management, and military.

For those VMEs that represent a contaminant risk, the phytosanitary measures recommended are detailed in the ISPM, and cover cleaning, prevention and disposal requirements. These include cleaning using pressure washing or compressed air cleaning, chemical or temperature treatments, storing and handling VMEs that prevent contact with soil, and keeping vegetation short around storage areas of ports.

The objective of this measure is to prevent unintentional introductions and spread of *L. americanus*.

SCALE OF APPLICATION

This measure should be applied at the EU scale and at an individual Member State level for all commodities at risk (especially, vehicles, machinery, equipment, as well as soil and gravel from river banks) coming from a country or area where *L. americanus* is already established. This measure would need to be applied across the EU, as once VME or soil/gravel have been imported into the EU, they could be moved to high risk areas.

EFFECTIVENESS OF MEASURE

Neutral.

Soil from all third counties will soon be prohibited from importing into the EU, therefore the issues that need to be addressed are as a contaminant of soil attached to VMEs, and the movement/import of soil between Member States. Any inspection of commodities at risk, or restrictions on the import of soil, could reduce potential unintentional introductions. However, given that there is generally no or very few human activities (soil extraction, sylviculture) in natural areas where *L. americanus* is established (wet or temporary waterlogged forests), and given that there are no evidences of unintentional introduction of *L. americanus*, it seems that this measure will not be very cost-effective for this species considering the chance to detect a seed and the volume of goods to inspect.

Moreover, it is difficult to assess whether VMEs present a risk, and therefore when to apply the relevant phytosanitary measure (IPPC, 2017). The ISPM provides a number of elements to consider when assessing risk; distance of

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

movement (shorter distances are a lower risk), complexity of VME structure (more complex are a higher risk), origin and prior use (VME in close proximity to vegetation a higher risk), storage (VME stored outside near vegetation are a higher risk), intended location or use (VME for use in agriculture, forestry, or close proximity to vegetation are a higher risk). In addition, the inspection, cleaning and treatment will normally take place in the exporting country to meet import requirements. In relation to extra-EU imports, there are no EU regulations on phytosanitary requirements for imports of VMEs. Therefore, for the measure to be effective either regulations need to be developed to regulate VME imports, or inspections and phytosanitary measures would need to be applied at EU ports and also at EU/non-EU border facilities.

EFFORT REQUIRED

This measure needs to be applied permanently and all year-round (as VMEs and soil at risk can be imported or moved at any time of the year).

RESOURCES REQUIRED

In relation to import of VMEs into the EU the resources required include the staff time of an inspector to check for compliance against any standards put in place.

In relation to movement/import of VMEs between Member States, facilities will be required for the cleaning, and treatment of VME and may include: – surfaces that prevent contact with soil, including soil traps and wastewater management systems – temperature treatment facilities – fumigation or chemical treatment facilities (IPPC, 2017). In addition, trained staff are required to undertake the inspections and phytosanitary measures, and suitable disposal facilities especially if implemented within the EU.

If soil movement/imports between EU Member States were to be regulated with inspections for contamination of *L. americanus*, resources would need to include identification keys for seeds and train phytosanitary inspectors to identify seeds of *L. americanus*. The seeds of *L. americanus* are grey-brown to red-brown, (3-)5-11 mm (EPPO, 2006). However, the measure will need repeated effort to detect the seeds among the commodities (soil for example) and continually inspect consignments and commodities at risk.

SIDE EFFECTS

Environmental: Positive
Social: Neutral or mixed
Economic: Negative

Economic effects: Increased effort will be required to inspect all commodities at risk (for example, machinery, soil). Public works contractors and all economic sectors involved in international or national VMEs (such as sylviculture) and soil transportations may be negatively impacted by this measure.

Environmental effects: Seeds of other invasive plants, including at least two other species of Union concern (*Impatiens glandulifera*, *Parthenium hysterophorus*) could be included in the measure (same commodities) and therefore also intercepted and destroyed.

Social effects: None to detail.

The plant is called skunk cabbage because of the distinctive "skunky" odour that it emits when it blooms. © Zygmunt Dajdok.

ACCEPTABILITY TO STAKEHOLDERS

Neutral or mixed.

This kind of measure could receive large acceptance from the public who can see that Member States are acting pre-emptively against invasive alien species. Stakeholders involved in international or national VMEs and soil transportations may be negatively impacted by the increased costs of their activities as a result of this measure. If equipment would be required to be cleaned and inspected on a regular basis, some organisations would not approve of it and this measure would be met with lots of negativity by private companies.

ADDITIONAL COST INFORMATION

Implementation cost for Member States: Implementation costs for Member States are likely to be high, as significant amounts of staff time from phytosanitary inspectors would be required. Member States would be required to maintain monitoring over a long period. Note, however, that these costs will be shared over several species, at least *Impatiens glandulifera* and *Parthenium hysterophorus* for the commodities identified at risk for *Lysichiton americanus*.

Cost of inaction: At this stage, cost of inaction may be considered as relatively low. The species can be considered as relatively easily detectable (see section *Surveillance measures to support early detection* below), its spread capacity is low (EPPO, 2009) and eradication at early stage is very cost-effective.

Cost-effectiveness of the measure: As detailed under Measure description and Effectiveness of the measure, phytosanitary inspections are not likely to be cost effective, due to both the large volume of commodities that are exchanged and the low probability of unintentional introduction of *Lysichiton americanus* through these pathways.

Socio-economic aspects: None to detail.

LEVEL OF CONFIDENCE*

Established but incomplete.

There are few documents to support the information given for this measure but the main source is an official standard (IPPC, 2017) with high generic value, so even if no specific information is available for *L. americanus*, we consider that the information provided are established but may be incomplete.

* See Appendix

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

Prevention of spread related to management of infested sites, movement of soil and vehicles used in infested sites.

MEASURE DESCRIPTION

While it seems unlikely that fragments of stem or rhizome could be spread by machines and vehicles used for sylviculture, as in construction of lanes, or tree cutting and transportation (EPPO, 2009), it is however expected that the movement of soil including attached to vehicles, machines and equipment (VMEs), may spread seeds of the plant during sylviculture work or during maintenance work in infested areas (for example, cleaning of ponds, etc) (EPPO, 2009).

Identification guides, factsheets, and codes of conduct should be developed to restrict the movement of potentially contaminated soil (of any IAS of Union concern) to areas free from invasion (but see *Secondary spread* section below).

Therefore, the implementation of biosecurity best practices is needed in known infested sites, to prevent secondary spread. This measure consists of:

- The development and implementation of soil management plans (basically restricting movement of soil from infested areas).
- The inspection, cleaning and treatment of vehicles, machines and equipment that have been used in infested areas (such as for sylvicultural works).
- The inspection and cleaning of the vehicles used in the management of invasive stands of *L. americanus.*
- Good practices of management of *Lysichiton americanus* and appropriate disposal of waste of the managed plants. For example, before excavating the plants (see *Rapid eradication* section), the inflorescences of the plant can be cut before uprooting in order to avoid seed dispersal and the enrichment of the seed bank.

Once the plants have been removed (including all the underground system), all plant material should be destroyed through either burning, drying out (well away from water) or secure composting. If removal is performed by mechanical means, it is essential to ensure that any equipment used is cleaned thoroughly before it is removed from site (RAPID, 2018).

SCALE OF APPLICATION

This measure should be applied locally, in all areas where *L. americanus* has established populations.

EFFECTIVENESS OF MEASURE

Effective.

While there is no evidence that this measure would be effective, it is the author's opinion that it would be likely to reduce the risk of secondary spread of *L. americanus.* In addition, as vehicle and soil movements from infested areas are limited, it should be seen as cost-effective as it can be implemented with relatively low economic impact for the sectors concerned (sylviculture, IAS management).

EFFORT REQUIRED

This measure needs to be applied all year-round until eradication of the species has been confirmed (as VMEs and soil at risk can be imported at any time of the year).

RESOURCES REQUIRED

The resources required include the staff time for cleaning the VMEs. Facilities required for the cleaning and treatment of VME may also include: – surfaces that prevent contact with soil, including soil traps and wastewater management systems – temperature treatment facilities – fumigation or chemical treatment facilities (IPPC, 2017).

Waste management of *L. americanus* after management require additional resources.

SIDE EFFECTS

Environmental: Positive
Social: Neutral or mixed
Economic: Negative

Economic effects: Increased effort will be required to clean vehicles, machinery and equipment. These costs will be borne by companies that used the VMEs (Public works contractors, sylviculture, etc.) that may be negatively impacted by this measure.

Environmental effects: Cleaning of the VMEs, would also intercept seeds of other invasive species and prevent their spread.

Social effects: None to detail.

ACCEPTABILITY TO STAKEHOLDERS

Neutral or mixed.

This kind of measure could receive large acceptance from the public who can see that Member States are acting pre-emptively against invasive alien species. Stakeholders that will have additional working time and cost for cleaning VMEs will be negatively impacted by this measure. However, the number of locations of *L. americanus* is low at the EU scale and in many cases it is unlikely that wet forests and wetlands where the species is established are used for exploitation of wood or soil. Therefore, there is a low risk that sylviculture companies consider this measure as unacceptable.

ADDITIONAL COST INFORMATION

Implementation cost for Member States: Implementation costs for Member States will be low as the costs will be bear by private companies.

Cost of inaction: absence of measures to prevent secondary spread from existing infestations would mean that control of populations is useless since it may lead to new infestations. Cost of inaction could be considered as being at least as high as the cost of management.

Cost-effectiveness of the measure: Preventive measures such as cleaning of VMEs that were used in infested areas in order to prevent secondary spread are likely to be cost effective, due to the high probability that soil is contaminated with seeds of *L. americanus.*

Socio-economic aspects: None to detail.

LEVEL OF CONFIDENCE[1]

Established but incomplete.

There are few documents to support the information given for this measure but the main source is an official standard (IPPC, 2017) with high generic value, so even if no specific information is available for *L. americanus*, we consider that the information provided are established but may be incomplete.

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 using a combination of active surveys and citizen-scientists.

MEASURE DESCRIPTION

Visual detection of plants in the field is the only feasible early detection method for new occurrences of *L. americanus* in the Union. It is possible to identify the species in the field with very little training, as there are no look alike species in the European flora (it will be hard to confuse with the native *Araceae* species (*Arum* spp.) whose leaves and inflorescences are much smaller). It should not be confused with *Lysichiton camtschatcense*, which is similar in appearance to *L. americanus* but slightly smaller in size and whose flower has white spathes rather than yellow. *Lysichiton camtschatcense* is mainly cultivated but some individuals were found in the wild in Germany (Alberternst and Schmitz, 2003) (the species is not regulated, so it is important to distinguish it if monitoring private gardens). This makes the species suitable for identification through citizen-science programmes.

A significant network of stakeholders is required to monitor all potential areas where *L. americanus* may occur, though sites most at risk are wetlands, wet forests, border of streams and rivers. High risk areas, such as those up and downstream of known infestations (including in neighbouring Member States) could be specifically targeted by repeated active surveying (for example, by relevant government agencies with engagement with local environmental groups/NGOs) while detection across the broader landscape is dependent upon citizen-science programmes.

SCALE OF APPLICATION

This measure can be undertaken at the sub-catchment level, but needs to be applied over the area of the Union where *L. americanus* is not yet present but has a high probability of establishment according to bioclimatic modelling (EPPO, 2009). Priority should be given to the monitoring of areas near established populations and within these areas in habitats most at risk such as swamps, wet woodlands, along streams and rivers, lakesides, ponds, boggy and other wet areas from 0-1400 m altitude (EPPO, 2006; Kligenstein and Alberternst, 2010).

EFFECTIVENESS OF MEASURE

The different stages of *Lysichiton americanus* are relatively easy to identify. Readily available field guides (for example, Fried, 2017) can be used to identify the species.

According to EPPO (2006), "the leaves are shortly petiolate and entire, ovate, cuneate to subtruncate at the base, the apex obtuse to acute, large (40-120×27-70 cm) and shaped like a tobacco leaf, leathery in texture, with a light sheen and with thick veins. Plants are generally erect, from relatively short to 1.5 m high. *L. americanus* develops one or two inflorescences per plant, with scape shorter than the leaves. The inflorescence is a showy bright yellow spathe (8-45 cm high), surrounding a fleshy spadix (8-25 cm) which bears small green flowers. Flowers are yellowish green, generally many, often monoecious (pistillate below,

The plant was used by indigenous people as medicine for burns and injuries, and for food in times of famine, when almost all parts were eaten. © Tim Adriaens, INBO.

staminate above), but sometimes also bisexual. The perianth segments are generally 4, sometimes 6, free or fused; tepals 4, stamens generally 0 or 4, sometimes 6, free or fused; ovaries (1-)2-locular; ovules 1-2, superior to half-inferior and sunken in inflorescence axis, chambers 1-3, stigma more or less sessile. The spadix is initially shorter than the spathe, eventually long exerted through elongation of the stipe. After flowering, fruits (150-350 green berries) develop along the spadix. Each berry usually contains 2 (sometimes 1-4) grey-brown to redbrown seeds (5-11 mm)."

Visual detection is commonly used by amateur and professional botanists and naturalists for recording *L. americanus* in the field.

EFFORT REQUIRED

In the case of a species already widely established in the Union, such as *L. americanus*, surveillance should be applied on the long term as part of the surveillance system of invasive alien species of Union concern required by Article 14 of the EU regulation No 1143/2014 on invasive alien species.

The period of surveillance would be from spring to autumn with more intensive surveillance during May-June when the plant has reached its full vegetative development and is more easily detectable.

If identified before flowering, there is the opportunity to eradicate the population (see section *Rapid eradication*). If the plant has released the seeds, the population would need to be monitored and further control measures would be needed the following seasons.

RESOURCES REQUIRED

Resources would involve staff time and travel costs in relation to active surveys, and if local groups/NGOs are being utilised there may need to be engagement activities (training workshops etc.). Total costs of a monitoring programme will depend on the area surveyed. Efforts could be shared with the monitoring of other invasive alien species of Union concern requiring similar surveillance in riparian habitats, especially *Impatiens glandulifera* and *Parthenium hysterophorus*. In terms of citizen-science, the production of information sheets, and a recorded system with validation of records needs to be developed however many IAS data recording smart phone apps already exist at a national and also EU level (for example, by the EC's European Alien Species Information Network – EASIN[2]).

SIDE EFFECTS

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

The surveillance of *L. americanus* can lead to the detection of other invasive alien species. The measure *per se* has low environmental impact and low cost to implement. Obtaining access to discrete private areas of land may, however, be problematic with the division of land ownership. Thus, despite intensive surveys, if the species is not controlled at a catchment scale, seeds of remaining undetected populations can become incorporated into the waterbody and spread to colonise new areas (see section *Prevention of secondary spread*).

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

The visual detection of *L. americanus* is likely to be acceptable to stakeholders and no significant impacts are envisaged. However, it should also be noted that local stakeholders (such as landowners) may choose not to report findings to avoid associated management costs (Tanner, 2017).

ADDITIONAL COST INFORMATION

Implementation cost for Member States: Depending on the area to survey, the implementation costs will vary considerably. There is no example for *L americanus*. However, in southern France, a similar approach was used to survey a 80 km of river to detect *Humulus scandens* in 2012 and 2014, for a total cost of €13,000 (Fried, 2018). Engagement with the local environmental NGOs, citizen-scientists and utilisation of volunteer networks can partly reduce these costs. Finally, some regional training workshops would probably be needed to train stakeholders in identification, management and safety aspects. It is estimated that each training workshop may cost €3,000 (Tanner, 2017).

Cost of inaction: Regular surveillance can lead to detection of small populations that are easy to control at very low cost. Thus inaction at this stage will lead to increase later cost of control when the population is well established.

Cost-effectiveness of the measure: This measure has the potential to be very cost effective if Member States can cooperate with local natural history or botanical societies, and utilise their expertise. Regional funding should be made available to local NGOs to monitor all potential invasive alien plants. The monitoring of *Humulus scandens* on the Gardon river by a team of two people has been estimated at €167/km to survey (Fried, 2018).

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

LEVEL OF CONFIDENCE*

Established but incomplete.

Few documents exist but the information provided is consistent.

2 https://easin.jrc.ec.europa.eu/easin/CitizenScience/About
* See Appendix

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

Manual control using a sharp spade to dug out plants.

MEASURE DESCRIPTION

This measure includes different steps (Charron and Blottière, 2018):

- (1 Optional) As a precautionary measure, the inflorescences of the plant can be cut before uprooting in order to avoid seed dispersal and the enrichment of the seed bank (see section on *Prevention of secondary spread of the species*).
- (2) Dig around the base of the plant with a spade to remove the soil until the rhizome is visible.
- (3) Cut the roots under the rhizome with the spade.
- (4) Slide the spade under the rhizome and use it as a lever to extract the entire plant.
- (5) All plant material should be destroyed through either burning, drying out (well away from water) or secure composting.
- (6 Optional) Sieve the first 5 cm of soil (from Step 2) from around the plant to remove a maximum number of seeds before filling in the holes. The purpose of this step is to deplete the seed bank more quickly.

Measures can take place during the whole growing season, but the best time is in early summer because this weakens the remaining rhizomes (Klingenstein and Alberternst, 2009)

Since only older plants (3 years or older) of *L. americanus* are producing seeds (E. Jörg, pers. comm., 2009), controlling the plants in an early stage of infestation results in a rapid decline of plants, as the example from Switzerland shows (see below).

SCALE OF APPLICATION

This measure has been applied on small to medium size infestations with scattered individuals over 500-1000 m^2 (Charron and Blottière, 2018). It has been successfully applied in the Netherlands and in Switzerland on a dozen to a hundred of plants, respectively (EPPO, 2009; Rotteveel, 2007). Over larger areas (several thousand of plants over >1000 m^2), rapid eradication is not possible but eradication remains an achievable aims in the longer term (such as Tanus in Germany, see *Management* section).

EFFECTIVENESS OF MEASURE

Effective.

The method is highly effective based on several field management experiences (Charron and Blottière, 2018; EPPO, 2006; 2009; Klingenstein and Alberternst, 2009; RAPID, 2018). Obviously, this is particularly the case for small outbreak of small-growing plants (Rotteveel, 2007).

About 20 plants at 2 locations in the Harz near Elendstal have been controlled successfully by this measure. Manual control has also been successfully applied in the Netherlands and in Switzerland on a dozen to a hundred of plants, respectively (EPPO, 2009).

EFFORT REQUIRED

Lysichiton americanus build up a seed bank which lasts for at least 8 years. Therefore, any treatment requires a long-term commitment to exhaust the seed bank and fully eradicate this species (RAPID, 2018).

Control measures should take place 2 times a year (late spring/early summer and late summer) in the first 4 growing seasons and at least one time (May to July) per year in the following years depending on the occurrences in the previous year (Klingenstein and Alberternst, 2009). Controlled areas have to be monitored the following years to repeat the treatment for plants that have survived or have been overlooked and for detecting new offspring (Klingenstein and Alberternst, 2009).

RESOURCES REQUIRED

The costs of control measures are not known for all countries, but they will differ significantly (EPPO, 2009).

In Switzerland, the successful eradication by manual control involved the following resources (EPPO, 2009):

- two people spent 4 hours digging out the 100 plants during the first year.
- in the following year, there were only about 20 plants to dig out and in 2005, and in 2006 just a few young individuals were found.
- In 2007 and 2008 no more plants had germinated.
- In the following years, staff time was required to monitor the site every second year for regrowth (S. Buholzer, pers. comm., 2009).

Total costs of eradication have been estimated to amount around €1,000, declining from €500 in 2003, to just monitoring costs from 2008 onwards (S Buholzer, pers. comm., 2009).

Its consumption can result in intestinal irritation and even death if consumed in large quantities. © Zygmunt Dajdok.

Equipment includes hand tools (sharp spade) and strong bags for disposal.

SIDE EFFECTS

Environmental: Neutral or mixed
Social: Positive
Economic: Positive
Environmental effects: *Lysichiton americanus* occurs in sensitive wetland habitats. Any treatments can have negative side-effects on the environment. Compared to chemical treatments or mechanical control, manual digging up of plant represents the methods with the less risk of impact on non-targeted species. However, digging up the plants disturb the soil so that some non-intended effects should still be expected.

Socio-economic effects: Eradication operations can have positive socio-economic effects. If they are carried out by volunteers, this can create a sense of cohesion among the local population and help to raise awareness on environmental issues and the issue of invasive species. For larger infestations of *L. americanus*, this can also be achieved through small contracts that can provide temporary employment to some people.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.
Manual control would be perceived as more environmentally acceptable to stakeholders compared to chemical applications, especially for environmental NGOs involved in management actions (see Klingenstein and Alberternst, 2009) but also for the general public.

ADDITIONAL COST INFORMATION

Implementation costs for Member States: The cost of an early eradication by manual control was estimated to €1,500 for small sites (EPPO, 2009).

Cost of inaction: The cost of eradication of small populations is very low (~€1,500) compared to the cost of managing widespread population. For example, in the Taunus, the total cost of eradication several thousands of plants during about 15 years amounted to €200,000.

Cost-effectiveness: Manual control is a labour intensive method but it is often the best suited method for controlling *L. americanus* in sensitive habitats (Klingenstein and Alberternst, 2009). Eradication at an early stage of invasion can be very cost-effective as shown by the case reported for Switzerland (€1,000) or the Netherland (EPPO, 2009).

Socio-economic aspects: None to report.

LEVEL OF CONFIDENCE[1]

Well established.
All the numerous reports give consistent information (Charron and Blottière, 2018; EPPO, 2006; 2009; Klingenstein and Alberternst, 2009; RAPID, 2018).

1 See Appendix

Chemical control.

MEASURE DESCRIPTION

Application of chemical herbicides may offer a tool for rapid eradication of *Lysichiton americanus* provided herbicides are licensed for use in or near water (Aldridge *et al.*, 2018). Experiments in the UK showed that two herbicides are efficient to control *L. americanus*:

- glyphosate applied at a concentration of 6 L/ha
- 2,4-D amine at a concentration of 4,5 kg/ha

The treatment should be applied when the plants are about half grown in May or June (NNSS, 2011) and repeated in late summer/autumn as required.

It is important to note that EU/national/local legislation on the use of plant protection products and biocides needs to be respected.

SCALE OF APPLICATION

Chemical control for eradication is supposed to be applied on larger area than manual control due to lower cost with increasing scale.

EFFECTIVENESS OF MEASURE

Effective.

The efficacy of herbicides is moderate to good for 2, 4-D amine at 4.5kg/ha or good for glyphosate at 6l/ha (RAPID, 2018).

A study conducted in 2010, at Lymington Reedbeds, England, UK (Chatters 2010) divided a site into two sections. A larger downstream section was treated with glyphosate (Roundup Pro Biactive) at a rate of 6 l/ha. A smaller, upstream section was treated with 2, 4-D Amine at 4.5 kg/ha. The plants sprayed with 2, 4-D amine were less healthy based on observations made soon after treatments. However, two months after the treatments, glyphosate achieved a far higher levels of control compared to 2, 4-D amine: most plants sprayed with glyphosate appeared to have been killed, whereas most of those sprayed with 2, 4-D amine were found to have new shoots. Finally, 6 months following the treatments, a limited survey did not find any *L. americanus* plants, suggesting that both herbicide applications may have been successful.

A study in the UK (EPPO, 2009) found that use of 2, 4-D amine in the month of May at a concentration of 9 l/ha eradicated *L. americanus* at a private garden in Sussex, whereas glyphosate did not eradicate *L. americanus* and caused only limited reduction of growth of the plants at a site in Scotland. No further information was available.

The reports from literature show that chemical control is not always efficient. This could be due to different conditions of application and different rate of application. Access for application of herbicides in wet woodland environments can be difficult, resulting in poor or inadequate control (NNSS, 2011).

EFFORT REQUIRED

Lysichiton americanus builds up a seed bank which lasts for at least 8 years (EPPO, 2009). Therefore, any treatment requires a long-term commitment to exhaust the seed bank and fully eradicate this species (RAPID, 2018).

Control measures should take place 2 times a year when the plants are about half grown in May or June and then in late summer/autumn (RAPID, 2018). Controlled areas have to be monitored the following years to repeat the treatment for plants that have survived or have been overlooked, and for new offspring.

RESOURCES REQUIRED

Resources required for chemical control include equipment, for example sprayer backpack (€150), spray applicator or weedwiper, staff time, travel costs, safety equipment. Repeated visits would be needed over with two treatments per year at least during four years.

Application of herbicides is relatively cheap, and eradication costs could be as little as €600 per hectare in the UK (EPPO, 2009). Between 2010 and 2013, control of *L. americanus* has cost the New Forest Non-Native Plants Project over £6,000, and the work was not fully completed by that date (Woodland Trust, 2013).

SIDE EFFECTS

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

Environmental effects: Often there are restrictions on the chemicals that can be used, if any, due to the sensitivity of the invaded habitat. Non-target damage of native plants is a negative side effect of this control method. Herbicides which are effective on *L. americanus*, such as glyphosate will also kill other plants growing close by 1-2 m from the target plant (RAPID, 2018). 2, 4-D amine is a selective herbicide that kills broadleaf plants, so that other non-targeted species will be killed and it could also be harmful to fish.

Lysichiton americanus occurs in particularly sensitive wetland habitats, so that any chemical treatments can have negative side-effects on the environment and many stakeholders will avoid this method (Klingenstein and Alberternst, 2009).

To reduce side-effects, one can use the method of stem injection. For this purpose, stem injection equipment should be used to inject a dose of herbicide directly into the taproot of established plants or make a hole in the centre of the plant using a small spade or pinch bar and spray herbicide onto the white stump (RAPID, 2018).

Another adverse consequence of chemical control is that it can leave bare soils thereby adding to the potential for new colonisation by *L. americanus* seedlings and/or other invasive alien species. Indeed, it has been observed in UK that following *L. americanus* management by chemical control, some of the cleared areas are now being infested with another invasive alien species (*Impatiens glandulifera*) which causes its own serious problems (Chatters, 2010).

Socio-economic effects: none to report.

ACCEPTABILITY TO STAKEHOLDERS

Neutral or mixed.

Chemical control to eradicate invasive alien plants is controversial and may be viewed negatively by stakeholders due to numerous potential non-target damages on resident vegetation and due to contamination of water (Klingenstein and Alberternst, 2009). This is especially the case in sensitive habitats where *L. americanus* is usually establishing (wetlands, waterlogged forests). In addition, there will be many areas where chemical application is not allowed for example in the near vicinity of standing water, for example, along rivers, sites of conservation value, etc. However, chemical control might be accepted locally (for instance, over smaller areas) for rapid eradication.

ADDITIONAL COST INFORMATION

Implementation costs for Member States: Among the available methods for eradication, chemical control is relatively cheap as it has been estimated at €600/ha (EPPO, 2009).

Cost of inaction: The cost of eradication of small populations is very low (<€600) compared to the cost of managing widespread population. For example in the Taunus, the total cost of eradication several thousands of plants during about 15 years amounted to €200, 000.

Cost-effectiveness: Chemical control is a cost-effective method for controlling small populations of an *L. americanus* (EPPO, 2009).

Socio-economic aspects: None to report.

LEVEL OF CONFIDENCE[1]

Well established.

All the reports give consistent information.

1 See Appendix

Measures for the species' management.

Integrated management for short-term containment and long-term eradication.

MEASURE DESCRIPTION

Integrated management includes a combination of all available methods detailed in the *Rapid eradication* sections, including manual and chemical control. However, while chemical control might be accepted locally for rapid eradication, it is less certain that this method will be accepted for large-scale and long-term applications.

The aim of this measure is to contain the plant, reduce its density below an impact threshold and eventually eradicate the population at longer term. Given that the plant has medium spread capacity (EPPO, 2009), that it spreads slowly within a site (Klingenstein and Alberternst, 2009) and that it reproduces sexually only from 3 years onwards (RAPID, 2018), the aim of eradication is realistic for numerous (or almost all) populations of *L. americanus* within a Member State, or part of a Member State's territory (EPPO, 2006; Panetta, 2015).

If no funds are available for achieving eradication during the first years, the spadices (the inflorescences) should be cut each year in order to avoid spread (Charron and Bllotière, 2018). Priority should be given to populations near river systems to reduce the risk of spread of the plant downstream. Priority should also be given to the most sensitive areas to limit the negative impact of the plant on native vegetation and ecosystem (EPPO, 2009; Sanders, 2013).

It is important to note that EU/national/local legislation on the use of plant protection products and biocides needs to be respected.

SCALE OF APPLICATION

Manual control of *L. americanus* has been applied in Tanus in Germany for controlling several thousand of plants over a large area (no detail information on the surface was available).

EFFECTIVENESS OF MEASURE

The method is labour intensive at this scale but it is effective based on experiences developed in the Taunus Nature Park (Klingenstein and Alberternst, 2009).

EFFORT REQUIRED

Lysichiton americanus build up a seed bank which lasts for at least 8 years. Therefore, any treatment requires a long-term commitment to exhaust the seed bank and fully eradicate this species (RAPID, 2018).

In the Taunus Nature Park, after the first control attempts in 2001, at least 15,000 plants were removed from 15 sites in 2004. In the following years, additional sites were found (27 in all in 2015). In 2006, about 15,000 plants were removed and fewer than 1,000 plants since 2010. In 2015, less than 10 plants were found on 23 controlled sites and no plants on 6 sites (Alberternst and Nawrath, 2015). According to these authors, managing a site with widespread populations requires between 5 and 15 years of continuous control and monitoring depending on the initial infestation size.

RESOURCES REQUIRED

Between 2001 and 2013, the management of *L. americanus* in the Taunus Nature Park, required an estimated 5,000 hours of work done by 100 volunteers, including for scientific support, public relations and volunteer procurement. If, in a comparable case, an average hourly wage of €40 was used for the appraisers, the forestry workers and the assistants, the costs amounted to approximately €200,000. Although the total elimination in the whole area is still pending, it has been shown that in places with only a few individuals (<100), usually after 4 to 5 years of constant managing and monitoring, the plant can be eradicated (Alberternst and Nawrath, 2015).

Equipment includes hand tools (sharp spade) and strong bags for disposal.

SIDE EFFECTS

Environmental: Neutral or mixed
Social: Positive
Economic: Positive

Environmental effects: Lysichiton americanus occurs in sensitive wetland habitats. Any treatments can have negative side-effects on the environment. Compared to chemical treatments or mechanical control, manual digging up of plant represents the methods with the less risk of impact on non-targeted species. However, digging up a large number of plants from dense stands of *L. americanus* disturb the soil so that there are still some non-intended effects.

Socio-economic effects: Eradication operations can have positive socio-economic effects. If they are carried out

The short-stalked leaves are the largest of any native plant in the region, 30–150 cm long and 10–70 cm wide when mature. © Zygmunt Dajdok.

by volunteers, this can create a sense of cohesion among the local population and help to raise awareness on environmental issues and the issue of invasive species. For larger infestations of *L. americanus*, this can also be achieved through small contracts that can provide temporary employment to some people.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

Integrated control is generally perceived positively by the general public as far as no chemical methods is used.

ADDITIONAL COST INFORMATION

Implementation cost for Member States: cost could be high with an estimation of €200,000 for managing 30, 000 individuals during more than ten years. These costs could be reduced by using volunteers (Alberternst and Nawrath, 2015).

Cost of inaction: at this stage (widespread population), inaction implies further spread of the species and eventually increased probability of new sites colonisation. Given the relatively slow spread of the species, the technical feasibility of its management and its eradication, it is still relevant to manage widespread population to reduce further cost.

Cost-effectiveness: none to detail.

Socio-economic aspects: none to report.

LEVEL OF CONFIDENCE[1]

Established but incomplete.

The only information available for long-term management of *L. americanus* is based on the experience developed in the Taunus Nature Park (Alberternst and Nawrath, 2015; Klingenstein and Alberternst, 2010). While the information is consistent it should be completed with other case studies.

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.

- **Well established:** comprehensive meta-analysis or other synthesis or multiple independent studies that agree. *Note:* a meta-analysis is 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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