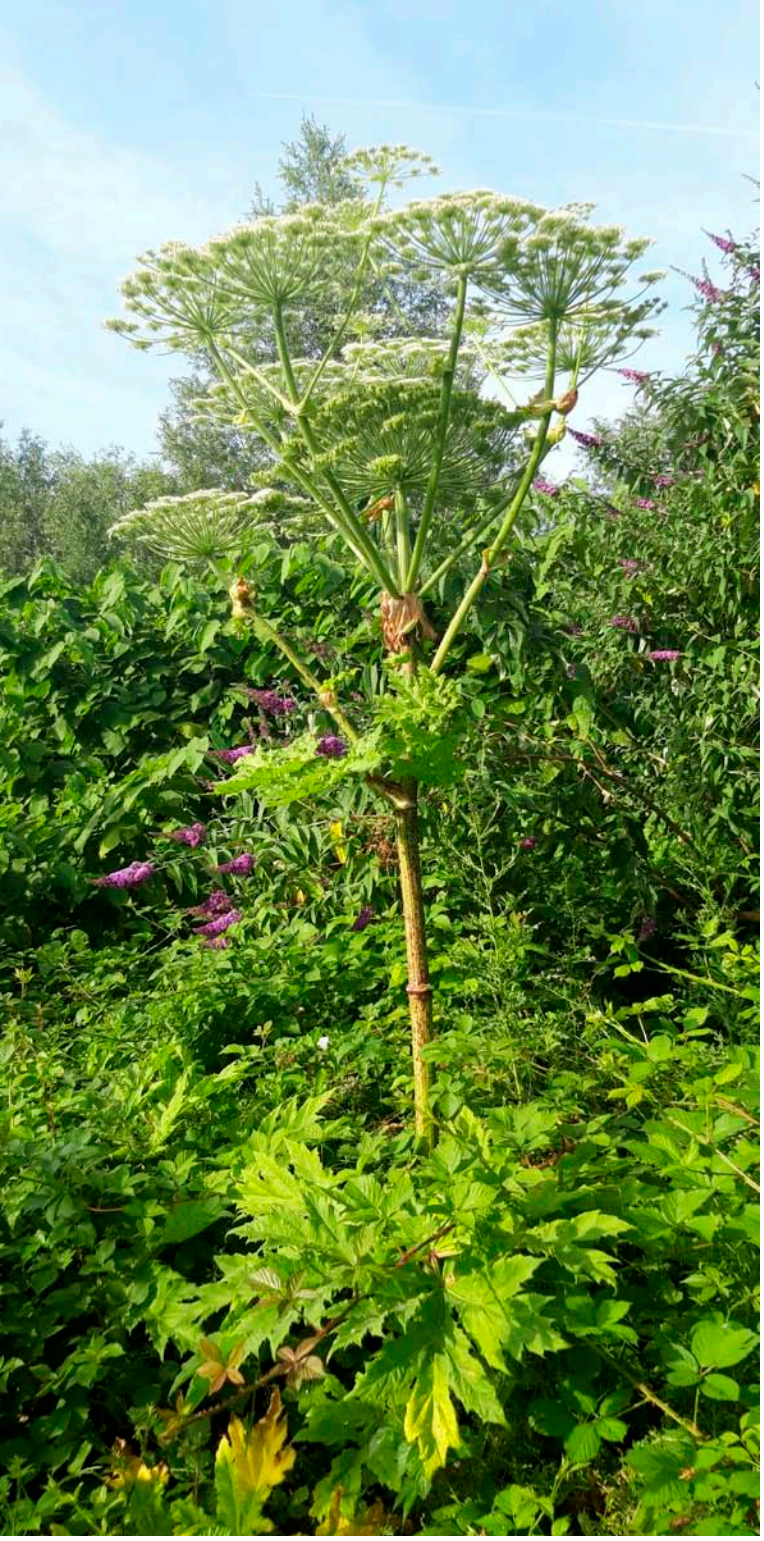

Heracleum mantegazzianum, Heracleum sosnowskyi, Heracleum persicum. © *Tim Adriaens, INBO*

The management of hogweed species (*Heracleum* spp.)

Measures and associated costs

Table of contents

Scientific name(s)	*Heracleum mantegazzianum, Heracleum sosnowskyi* and *Heracleum persicum*
Common names (in English)	Giant hogweed (*Heracleum mantegazzianum*), Persian hogweed (*Heracleum persicum*) and Sosnowskyi's hogweed (*Heracleum sosnowskyi*)
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Common names for *Heracleum mantegazzianum*

BG Гигантски хераклеум
HR Divovski svinjski korov
CZ Bolševník velkolepý
DA Kæmpe-bjørneklo
NL Reuzenberenklauw
EN Giant hogweed
ET Hiid-karuputk
FI Kaukasianjättiputki
FR Berce du Caucase
DE Riesenbärenklau
EL –
HU Kaukázusi medvetalp
IE Feabhrán capaill
IT Panace di Mantegazzi
LV Mantegaca latvānis
LT Mantegacio barštis
MT –
PL Barszcz Mantegazziego
PT –
RO Crucea Pământului
SK Boľševník obrovský
SL Orjaški dežen
ES Perejil gigante
SV Jätteloka

Common names for *Heracleum sosnowskyi*

BG Сосновски девисил
HR Sosnowskijev svinjski korov
CZ Bolševník Sosnowského
DA Rundlobet bjørneklo
NL Sosnowsky's berenklauw
EN Sosnowskyi's hogweed
ET Sosnovski karuputk
FI Armenianjättiputki
FR Berce de Sosnowsky
DE Sosnowskyi Bärenklau
EL –
HU Szosznovszkij medvetalp
IE –
IT –
LV Sosnovska latvānis
LT Sosnovskio barštis
MT –
PL Barszcz Sosnowskiego
PT –
RO Brânca ursului
SK Boľševník Sosnowského
SL Sosnovskijev dežen
ES –
SV Bredloka

Common names for *Heracleum persicum*

BG Персийски девисил
HR Perzijski svinjski korov
CZ Bolševník perský
DA Hårfrugtet bjørneklo
NL Perzische berenklauw
EN Persian hogweed
ET Pärsia karuputk
FI Persianjättiputki
FR Berce de Perse
DE Persischer Bärenklau
EL –
HU Perzsa medvetalp
IE –
IT –
LV Persijas latvānis
LT Persinis barštis
MT –
PL Barszcz perski
PT –
RO –
SK Boľševník perzský
SL Perzijski dežen
ES Golpar
SV Tromsöloka

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

All the three invasive hogweeds, giant hogweed (*Heracleum mantegazzianum*), Sosnowskyi's hogweed (*H. sosnowskyi*) and Persian hogweed/Tromsø palm (*H. persicum*) are closely related species that share almost similar life history traits. While *H. mantegazzianum* is already widely established and distributed in Europe (DAISIE, 2009; NOBANIS, 2015), *H. sosnowskyi* and *H. persicum* are only distributed in northern European countries. *H. sosnowskyi* is distributed mainly in the post-soviet countries (Latvia, Lithuania, Estonia, Belarus, Poland, Russia and Ukraine), where it occurs as a result of intentional planting for forage (Nielsen *et al.*, 2005; EPPO, 2009; Baležentienė *et al.*, 2014). Because of its similarity to other invasive hogweeds, in some countries its distribution is not precisely known (Poland, Hungary). Persian hogweed is distributed only in Fenno-Scandinavia (Denmark, Finland, Norway, Sweden), in spite of the frequent introductions to European gardens (EPPO, 2009; Alm, 2013). These differences in distribution are reflected in the number of studies available for each species, with most of them referring to the giant hogweed. As Sosnowskyi's hogweed is widely distributed in the European part of Russia, there are a lot of descriptive studies available in Russian. Studies on Persian hogweed are almost lacking in all territories.

PREVENTION OF UNINTENTIONAL INTRODUCTIONS AND SECONDARY SPREAD

For all species, secondary spread via unintentional transport of seeds, for example via contaminated soils, is likely the most important pathway that needs to be addressed to prevent introductions of the species into new areas. While the active spread of the species by humans is minimal, it is recommended that biosecurity measures at contaminated sites need to be introduced to minimise the risk of the transport of seeds to areas and countries where the species are not yet established.

EARLY DETECTION

The priority for early detection to allow for rapid eradication of the hogweeds is through the use of citizen science to identify new locations, and the active monitoring of high risk sites using field surveys and/or remote sensing.

RAPID ERADICATION

Rapid eradication of small populations is undertaken relatively easily by root cutting/spring digging, or by use of herbicides, although eradication of large infestations can be problematic. The only effective way currently known to eradicate all the three hogweeds is through the use of herbicides or the removal of rootstock by digging to about 5-15 cm below ground under the root (Pyšek *et al.*, 2007b). At small scales, it is possible to achieve eradication by covering soil with plastic sheets (Suadicani *et al.*, 2017). Mowing and grazing is not an efficient method to eradicate the species (Caffrey, 2001; Nielsen *et al.*, 2005; Pyšek *et al.*, 2007a), and there is no efficient biocontrol known in Europe (Pyšek *et al.*, 2007a; Seier and Evans, 2007). Due to good detectability of the plants prior to reproduction (due to their large size), absence of spread by vegetative fragments and high effectiveness of control techniques, their eradication may be easily achieved when effort is maintained over a period of several years (circa up to 10 years)[1]. Strategies required to achieve eradication can be divided along the scale of the infested area (see Nielsen *et al.*, 2005; Pergl *et al.*, 2016; Rajmis *et al.*, 2017) and small and isolated populations are relatively easy to deal with (Wadsworth *et al.*, 2000; Panetta and Timmins, 2004; Branquart *et al.*, 2011; Pergl *et al.*, 2012).

MANAGEMENT

The following ecological characteristics of hogweeds are relevant for the management of the species:

- Hogweeds can reproduce only by seed;
- Giant hogweed and Sosnowskyi's hogweed reproduce usually only once and die after setting seeds;
- Persian hogweed may reproduce several years before dying;
- Giant hogweed and Sosnowskyi's hogweed have a short term persistent seedbank; the majority of seeds germinate within the first or second year;
- Hogweeds are species with extremely high potential for regeneration;
- All the species are sensitive to a wide range of herbicides.

If total eradication is not feasible (due to lack of resources), seed production needs to be limited (for example by mowing or grazing), and any management actions need to be planned systematically (such as prioritise remote sites, begin management actions in the upper basins first, and continue along the flow downstream).

Regarding the monocarpic ecology of giant hogweed management actions should target the reproduction stage to minimise the risk of seed production and transportation (Pyšek *et al.*, 2007b). Although the species has short-term persistence in soil seedbanks, with the majority of seeds germinating in the first and second year, a small proportion of seeds are able to survive for up to 7 years, requiring any management of giant hogweed stands to be monitored in

[1] www.nonnativespecies.org/downloadDocument.cfm?id=998

the medium term (Moravcová *et al.,* 2006, 2007a).In case of Sosnowskyi's hogweed, Moravcová *et al*., (2007b) found that there is an easy breaking barrier of seed dormancy that allows seeds to germinate already in autumn, when climatic conditions are favourable, and that the type of seedbank is transient (almost all seeds germinate in the first year). Despite this, a small proportion of seeds is able to stay in the soil longer, which requires monitoring of the managed sites in the medium term (5 years).There are no data on persistence of Persian hogweed, so management actions should target 10 years of monitoring.

Because giant hogweed and Sosnowskyi's hogweed die after flowering, there can be a distinction between the control of vegetative and fruiting/flowering plants. The removal of umbels is effective if carried out at the peak of flowering, or at the beginning of fruit formation (June to July). Umbels must be totally destroyed (for example burned); cutting whole flowering stems and leaving them on site is not recommended, as plants are able to develop germinable seeds even on cut individuals (Dawson and Holland, 1999; Pyšek *et al*., 2007b).All hogweeds are species with an extremely high regeneration ability, as flowering plants can re-sprout after damage and set seed within one month (Pyšek *et al*., 2007b).

If a long-term management programme is feasible (circa 10 years), only flowering plants of giant hogweed and Sosnowskyi's hogweed need to be targeted until the population is depleted. For large populations, mechanical control through grazing and cutting/mowing may help to reduce their size. However, timing of the measures is crucial, as if they are carried out too early, plants will regenerate and set viable seeds. Mechanical methods, such as grazing or mowing, are usually the only options suitable for areas used as organic farming land, buffer areas of water resources, or within protected areas.

Summary on management recommendations following Dawson and Holland (1999) and Pyšek *et al*., (2007b):

1. The only treatment that effectively kills hogweed plants is the destruction of the tap root at 15 cm depth below-ground, or the application of herbicides.
2. Timing of the cutting the aboveground parts of plants is crucial. If carried out too early, individuals will regenerate successfully.
3. The life stage of the targeted plants, and differences between giant, Sosnowskyi's and Persian hogweed, need to be taken into account when planning the management actions. If long-term management is feasible, only flowering plants of giant hogweed and Sosnowskyi's hogweed should be targeted, and vegetative individuals can be left until the population is depleted.
4. Umbels must be removed from the site. Even umbels cut at late flowering, or early fruiting, are able to produce viable seeds. Cutting whole flowering stems and leaving them at a site is not recommended.
5. If large scale eradication is not possible (for example extent or budget restrictions), reducing the number of seeds produced is important.

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 *Heracleum* spp.

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).]

Heracleum mantegazzianum, Heracleum sosnowskyi, Heracleum persicum. © *Tim Adriaens, INBO*

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

Biosecurity measures.

MEASURE DESCRIPTION

The giant hogweed is already widely established throughout Europe (DAISIE, 2009; NOBANIS, 2015).Sosnowskyi's hogweed is mainly distributed in the post-soviet countries (Latvia, Lithuania, Estonia, Belarus, Poland, Russia and Ukraine), where it occurs as a result of intentional planting for forage (Nielsen *et al.*, 2005; EPPO, 2009; Baležentienė *et al.*, 2014).Persian hogweed is distributed in Scandinavia and its history of introduction is unclear (Jahodová *et al.*, 2007a,b). Currently, there are no known intentional or unintentional introductions of the species from their regions of origin (*H. mantegazzianum* - the western Caucasus; *H. sosnowskyi* -

eastern and central Caucasus, Transcaucasia, and north-east Turkey; *H. persicum* - Turkey, Iran and Iraq), or they occur at a very low probability and volume (Pergl and Branquart, 2016). Nevertheless, as for example *H. sosnowskyi* is widely distributed in the whole European Russia (Afonin *et al.,* 2017), its introduction to Europe as a contaminant of soil and other materials is probable. In fact, the transport of soil as a commodity, or a contaminant, has been identified as a relevant introduction pathway for both *H. sosnowskyi* and *H. persicum* (EPPO, 2009).

Biosecurity measures to prevent unintentional introductions of seeds would need to include inspection of clothes, shoes, equipment, materials (for example soil) and vehicles for hogweed seeds at country borders, such as airports, ports and land borders. Regulation (EU) 2016/2031, which repealed 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, partly addresses this issue. In addition, ISPM Standard 41 on the 'International movement of used vehicles, machinery and equipment' recommends phytosanitary measures to reduce the risks of transporting unwanted contaminant products (for example soil, seeds) associated with the movement of vehicles, machinery and equipment (FAO, 2017). However, in practice, only a small proportion of these materials entering the EU are inspected at ports of entry for the transport of associated harmful organisms, and inspection intensity largely varies between EU Member States (Eschen *et al.,* 2015a, b). As such, a more stringent application of these measures would be needed.

SCALE OF APPLICATION

This measure should be implemented at a national scale, at border controls dealing with people and/or goods being imported from third countries.

EFFECTIVENESS OF MEASURE

Effective.

Effective, if applied comprehensively at border controls, as the species reproduces only by seeds, which are large and easily recognised (Burgiel *et al.,* 2006).

EFFORT REQUIRED

In order to prevent unintentional introductions from outside the EU, effective border inspections should be applied indefinitely.

RESOURCES REQUIRED

No special resources are needed for the identification of the species, but border control staff needs to be trained in the identification of seeds.

SIDE EFFECTS

Environmental: Neutral or mixed
Social: Neutral or mixed
Economic: Neutral or mixed
There are no expected side effects for the proposed measure.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.
Conflicts with stakeholders are not expected, especially if the measure is adopted alongside awareness raising activities.

ADDITIONAL COST OF INFORMATION

Although there is no cost information available for the implementation of this measure, no additional costs are expected. Training of staff can be included as part of other education programs.

LEVEL OF CONFIDENCE*

Established but incomplete.
There is no exact information about inspection of traded materials and the unintentional introduction of hogweeds from third countries across borders.

* See Appendix

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

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

Biosecurity standards.

MEASURE DESCRIPTION

Unintentional introductions via secondary spread within the European Union are likely to be much more important for these species than unintentional introductions from regions outside the EU (Alm, 2013; Pergl and Branquart, 2016). Hogweeds reproduce only by seeds, so minimising seed production and transport is crucial (Pyšek *et al.*, 2007b). As such, measures to prevent secondary spread of hogweeds should aim at controlling the unintentional transportation of seeds from already invaded to non-invaded areas. This would require prohibiting the movement of clothes, equipment, materials (for example soil) and vehicles from hogweed contaminated areas, or inspecting and enforcing decontamination of equipment and materials for hogweed seeds before movement from areas where the species is known to occur.

SCALE OF APPLICATION

This measure should be implemented at a national scale, and targeted at hogweed contaminated sites.

EFFECTIVENESS OF MEASURE

Effective.

Effective, if applied comprehensively at all hogweed invaded areas, as the species reproduces only by seeds, which are large and easily recognised (Burgiel *et al.,* 2006).

EFFORT REQUIRED

The period of time over which these measures need to be applied to hogweed invaded areas depends on local conditions and on the species in focus. For the giant and Persian hogweed, after a contaminated site has been eradicated, inspections need to be applied for up to 7 years after the last occurrence at a donor site, as a small proportion of seeds are able to survive in the seed bank for up to 7 years (Moravcová *et al.,* 2007a). As Sosnowskyi's hogweed forms a transient seed bank, post-eradication checks can be shortened to 5 years (Moravcová *et al.,* 2007b).

As all hogweed species reproduce only by seeds, actions should be taken especially in late summer and autumn, when seeds can be easily transported. In case of transport of soil, inspection and cleaning should be carried out independently of the time of the year.

RESOURCES REQUIRED

Resources needed to implement this measure include the costs of trained staff to inspect and enforce restrictions of movements from hogweed invaded areas, as well as materials and facilities needed to decontaminate equipment and machinery.

SIDE EFFECTS

Environmental: Neutral or mixed

Social: Neutral or mixed

Economic: Neutral or mixed

No major side effects are predicted. Partly negative economic effects can occur in highly infested areas, where inspection and cleaning of machinery can incur high costs, although no specific information on costs and time needed for this is available.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

Conflicts with stakeholders are not expected, especially if the measure is adopted alongside awareness raising activities. Increased costs related to inspection and cleaning of machinery from highly infested areas may reduce stakeholder acceptability, although this is not very likely.

ADDITIONAL COST OF INFORMATION

The cost of inaction can be high, as further spread of the species to areas where it is not already present, followed by eradication campaigns, can be costly (see below details on different methods).

LEVEL OF CONFIDENCE*

Established but incomplete.

* See Appendix

Heracleum mantegazzianum, Heracleum sosnowskyi, Heracleum persicum. © *Tim Adriaens, INBO*

Local spread, for example of *H. mantegazzianum*, is well described by several studies (for example Pergl *et al.*, 2012), but there is no exact information and there is a lack of studies about the spread of the different hogweed species across areas.

* See Appendix

Measures for early detection of the species and to run an effective surveillance system for an early detection of a new occurrence.

Citizen Science.

MEASURE DESCRIPTION

Early detection of hogweed species relies upon the reporting of new occurrences through citizen science and the active monitoring of high risk sites.

Giant, Sosnowskyi's and Persian hogweeds easily colonise new sites in vicinity of already existing stands (Thiele *et al.*, 2007; Kabuce and Priede, 2010; Baležentienė *et al.*, 2014; Pergl *et al.*, 2012). In the case of giant hogweed, it was shown that this spread is limited in areas where the plant has recently established (for example Belgium, France or Slovenia), compared to areas where it has been established for a long time (for example Czech Republic, Baltic countries and Germany) (Muller, 2004; Thiele and Otte, 2006; Pyšek *et al.*, 2008; Fried, 2009; Branquart *et al.*, 2011; Pyšek *et al.*, 2012), showing the importance of surveillance measures to support early detection of new occurrences of this species.

The identification of new occurrences through citizen science, mainly via the public, should be supported by awareness raising activities on these species. In sites where the occurrence of the species can be expected in the future, for example neighbouring areas to existing infestations, expert field surveys and remote sensing data (UAV, aerial photos) can be used for early detection of new occurrences (Müllerová *et al.*, 2013, 2017). Remote sensing (RS) has proven useful for monitoring various other invasive shrubs and trees (Huang and Asner, 2009).

SCALE OF APPLICATION

From regional (aerial detection, remote sensing) to national/EU (citizen science). For citizen science, the reporting applications can focus on various scales, from regional to continental scale. For RS and field surveys of high risk sites, the target areas need to be identified in advance by preliminary reports of species occurrence (for example through Natura 2000 sites; Baležentienė *et al.*, 2014), which may allow costs, and the efficiency of mapping, to be estimated.

EFFECTIVENESS OF MEASURE

Effective.

In terms of citizen science and public identification, even though the species is the tallest herbaceous plant in Europe and has an exotic appearance, reporting of new locations for example through smartphone applications (for example http://www.planttracker.org.uk; http://www.rinse-europe.eu/smartphone-apps, http://biolog.nature.cz/cz/Article/AboutApp and https://easin.jrc.ec.europa.eu/CitizenScienceAbout), is relatively resistant to bias of wrong identification.

For herbaceous species, RS is only effective if the target species is distinct from surrounding vegetation, forms dense and uniform stands, and/or is large enough to be detected. The flowers of giant hogweed are arranged in compound umbels, with the largest terminal umbel (up to 80 cm in diameter), and satellite and other umbels on branches (Perglová *et al.,* 2006). In Europe, giant hogweed flowers from June to July, followed by sequential ripening of fruits. Therefore, as has been documented (Müllerová *et al.,* 2005, 2017), the size, distinct shape, and colour of inflorescences enables recognition of individual plants, even on low quality panchromatic VHR aerial photographs, if acquired during the flowering or early fruiting period. Furthermore, populations are recognisable on satellite data of coarser spatial resolution (Rapid Eye) (Müllerová *et al.,* 2017).The flowering plants of *H. sosnowskyi* and *H. persicum* have similar architecture to *H. mantegazzianum*, which aerial detection has been widely proven (Kabuce and Priede, 2010; Baležentienė *et al.*, 2014). RS is less costly than the direct mapping by experts in the field, but is limited, in that only flowering individuals at open habitats can be recorded. Moreover, while RS detection of flowering individuals is relatively easy, that of fruiting or non-flowering plants is limited, with images capturing the species in the fruiting period (1973 panchromatic and 1987 multispectral aerial photography) showing significantly lower recognition success (Müllerová *et al.*, 2017). Fruiting plants without flowering umbels were not well separable from the surrounding vegetation; their spectral characteristics were not distinct enough, even on multispectral imagery (Müllerová *et al.,* 2017). The same study showed that non-flowering, fruiting, cut, sprayed or grazed individuals were difficult to identify on aerial photographs.RS by drones is limited to areas where UAV can be used (for example areas outside urban zones, roads).

Expert field surveys of high risk sites are highly effective (L. Pocová, pers. comm. 2017; Pergl *et al.,* 2012).

EFFORT REQUIRED

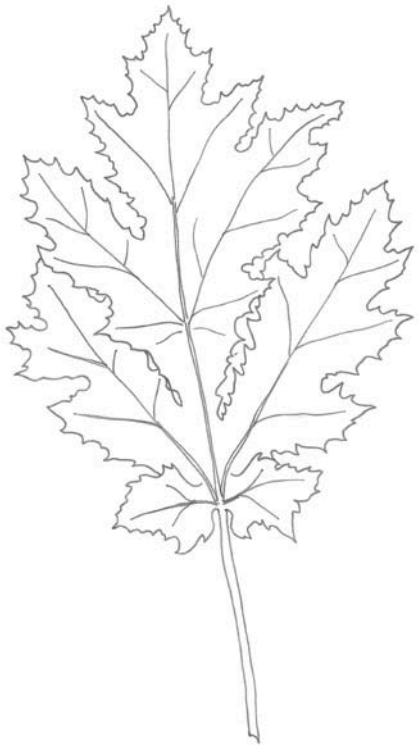
For citizen science, the effort required will be that of undertaking engagement activities, which should aim to inform the public of the best times of the year to easily identify the species (and the diagnostic characteristics).

The time needed for field mapping is comparable to that for other surveys, like for Natura 2000 sites. For RS, it is crucial to monitor the sites during the appropriate time of the year, as only certain phenological stages of the plants (flowering and early fruiting) are distinct enough to be accurately distinguished.

RESOURCES REQUIRED

For citizen science, mobile phone applications or other online platforms devoted to recording species occurrences may need to be developed, although many already exist (see examples above).Moreover, the resulting distribution data should be linked directly to the national agencies responsible for alien species management which, after verifying the records, should forward them to EU early warning systems.

Direct field surveys can be informed using preliminary data (for example from Natura 2000, citizen science, national or regional plant inventories), and are relatively cheap to undertake (ca. 1 Euro per ha, L. Pocová, pers. comm., 2017). Non-targeted field surveys can be part of other established monitoring programmes, for example for Natura 2000 sites, reducing the costs even more. Giant hogweed (and also Sosnowskyi's and Persian hogweeds) are species that can be easily identified and reported.



Heracleum montegazzianum. © *M. Lipperi*

For RS, aerial photographs, or detailed satellite data, are needed. The resources needed for this depend if the photographs still have to be taken, or if the analysis is based on existing data. If the area to be monitored is relatively small, then using drones is recommended, due to flexibility in area monitored, time restrictions and speed at which surveys can be undertaken relative to the area covered.Acquiring a drone is expensive, but might prove cost-effective in the long-term. The estimate of the costs for satellite photos range between 20 (satellite Pleiades) to 30 Euros (satellite WorldView-2) (J. Müllerová, pers. comm., 2018). The problem with satellite data is that it is low in flexibility and it depends on weather conditions (for example occurrence of clouds jeopardizes photos).

SIDE EFFECTS

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

No major side effects are expected from this measure. As hogweeds sap can burn human skin (phytophotodermatitis), the identification of new sites/records of the species through public engagement or active monitoring in the field, needs to include clear warnings not to handle the plant.

ACCEPTABILITY TO STAKEHOLDERS

Neutral or mixed.

Direct field surveys can be problematic to undertake in private properties; as such, it is important that access to private land is granted by land managers and landowners. The use of drones may also generate public opposition and can be limited by national legislation/regulations.

ADDITIONAL COST INFORMATION

Most of the EU Member States already have some information systems available for collating biodiversity data that are accessible for the public to submit records. Therefore, no extra costs for developing software are expected, unless specific smartphone applications are desired.

LEVEL OF CONFIDENCE*

Well established.

Citizen science has been largely used throughout Europe. For RS, there are several studies focused on giant hogweed recognition from aerial photos, with detailed descriptions and a wide range of approaches; the architecture of the other two hogweed species is similar, allowing this technique to be replicated.

* See Appendix

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

Digging out the roots.

MEASURE DESCRIPTION

Digging out the roots is the only mechanical method that immediately destroys hogweeds (Tileyand Philp, 1997; www.nonnativespecies.org/downloadDocument.cfm?id=998).

Root cutting can be applied to areas with relatively low plant coverage, and areas up to approximately 500 m^2 of coverage. Roots must be cut at least 10–15 cm below the ground, at the beginning of the growing season (April to June), and left on the ground to become dry. On wet habitats (for example river banks, meadows under tree canopies), roots need to be removed from the site, or placed on the foliage of the up-rooted plants without soil contact. Recommendations on efficient control from Denmark state that cutting only 2-3 cm below ground is sufficient (https://care4nature.dk/bekaempelse-kaempe-bjoerneklo/). The depth of root cut therefore depends on local conditions and position of adventive buds on roots (Pyšek *et al.,* 2007b).

Similar to root cutting is the so-called "spring digging", which is done early in the spring using a hoe, when the plants emerge (end of March-April). The advantage is that this is done when the plants are small, the root is only 5-10 cm deep and the risk of contact with leaves (and burning) is small (Pergl *et al.,* 2016).

SCALE OF APPLICATION

Small scale. This measure is suitable for relatively small areas or not so dense larger stands (circa up to 500 m^2) (L. Pocová, pers. comm., 2017; Rajmis *et al.*, 2017). A study from Denmark recommends root cutting to population sizes up to 10 000 individuals (Suadicani *et al.,* 2017).

EFFECTIVENESS OF MEASURE

Effective.

Very effective, if done properly (Tiley and Philp, 1997; Rajmis *et al.*, 2017). Cutting the tap root as a method for eradicating hogweeds comes from Tiley and Philp (1997), who studied the effect of cutting at different root depths and stem heights on regeneration. The authors found that cutting plants 5cmbelow the soil surface, or at ground level, allowed re-growth of shoots from axillary buds below ground. Such observation is in concordance with findings by Caffrey (1999), where no mortality was recorded among plants cut to ground level.

EFFORT REQUIRED

The best time of the year to undertake root digging is at the beginning of the growing season (April to June), in order to avoid problematic handling of flowering plants. Although the method is effective throughout the year, it must be done at the very beginning of the fruiting season, before the seeds are released. There is no need to repeat this measure for correctly treated plants, but it is necessary to revisit managed localities to control for overlooked individuals, regenerating plants and plants germinated from the soil seed bank (the same year, as well as for a minimum of 7 years for *H. mantegazzianum* and *H. persicum*, and of 5 years for *H. Sosnowskyi*).

RESOURCES REQUIRED

No special resources are needed; only labour, and digging and protection equipment (for example gloves) are required. See Rajmis *et al.,* (2017) and the table above for estimate of costs in Germany.

SIDE EFFECTS

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

The only risk associated with this method is the potential contact of workers with plant sap and resulting skin burnings (phytophotodermatitis). Therefore, it is essential to wear protective clothes.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

This measure is generally acceptable to stakeholders, and suitable even for organic farmers.

ADDITIONAL COST INFORMATION

No additional information.

LEVEL OF CONFIDENCE*

Well established.

There are a number of published studies confirming the use and effectiveness of this measure on giant hogweed. As Persian and Sosnowskyi's hogweed have the same life-history as the giant hogweed, and Sosnowskyi's hogweed has an even shorter living seed bank, the confidence level is high.

* See Appendix

Herbicide application.

MEASURE DESCRIPTION

Rapid eradication of small populations is undertaken relatively easily by use of herbicides, although eradication of large infestations can be problematic (Wadsworth *et al.*, 2000; Pluess *et al.*, 2012; Pergl *et al.*, 2016). Based on data from the Czech Republic, the ability to eradicate small populations of giant hogweed is high (Pergl *et al.,* 2016).

Hogweeds are sensitive to a wide range of herbicides (for example active component glyphosate, triclopyr; Nielsen *et al.*, 2005; Dalke *et al.*, 2018). The use of selective herbicides is recommended, so that the invaded area can be quickly overgrown with grasses, which suppress young hogweed plants and prevent the establishment of other non-native plant species. Depending on the area infested, the application can be in a form of spray or direct leaf application. In large areas with restrictions on the use of herbicides (for example organic farms, protected areas), only mechanical methods are allowed (Pergl *et al.*, 2016). However, the use of herbicides in environmentally sensitive sites can be addressed through the injection of herbicides into stems and roots of the plants.

EU/national/local legislation on the use of plant protection products and biocides needs to be respected. At a national level, it is recommended to certify people or companies carrying out control, in order to secure efficacy of the countermeasures (Suadicani *et al.*, 2017).

This measure can be used for both rapid eradication, as well as long-term eradication of hogweed species.

SCALE OF APPLICATION

Local to national scale (based on the level of invasion and local needs).

The table below summarises suitability of different methods for herbicide application (as well as approaches using different measures) for eradication control of giant hogweed, depending on the size of the infestation (Rajmis *et al.*, 2017).

EFFECTIVENESS OF MEASURE

Effective.

Target plants do not survive and, if the herbicide is applied at the right time, seeds are not produced (Pyšek *et al.*, 2007b). Total weed (and other vegetation) control by glyphosate application can be achieved in spring, when weeds have sufficient leaf area, and before they become widespread. Deep ploughing of the soil (up to 24 cm) three weeks later will almost totally eliminate the germination of hogweed seeds (Nielsen *et al.*, 2005).

EFFORT REQUIRED

In general, the application of herbicides is most effective in May, when the stands are accessible, leaf rosettes are fully developed and the average plant height reaches approximately 0.5m high. The spraying of herbicides should also be applied before the plants begin to form a flowering stem. After this, some herbicides do not work at the usual dose, and the required increase in concentration would not be appropriate for the environment (Pergl *et al.,* 2016). Injection of herbicides to the stem or root can be used for managing plants at sensitive conservation sites, where there is a risk of affecting the surrounding vegetation or the neighbouring environment[2].

RESOURCES REQUIRED

The resources required depend on the size of the infestation and on local salary settings, as the use of herbicides is labour intensive and requires trained staff.

2 www.nonnativespecies.org/downloadDocument.cfm?id=998

Area size	Root destruction with shovel	Mechanical cutting with scythe	Mechanical cutting with flail mower	Chemical treatment with hand-held equipment	Chemical treatment with machines	Grazing
Unprotected areas						
Small (up to 100 m^2	X	-	-	X	-	-
Medium (>100–1,000 m^2)	–	X	–	X	–	X
Large (>1,000 m^2)	–	–	X	–	X	X

Hogweeds are considered some of the most harmful IAS in Europe (Pyšek *et al.*, 2013; DAISIE, 2015), because of the risk of incurring human injuries (phytophotodermatitis), their high rate of spread and their impact on biodiversity; therefore, there are significant funds invested into their eradication (in many cases, eradication costs include campaigns for other IAS). The eradication costs of dense populations of giant hogweed are between 1,000 and 50,000 EUR/ha/year, depending on the control technique used (including both chemical and mechanical treatment) and site conditions. Much lower costs are, however, incurred to control low density populations (Nielsen *et al.*, 2005; Gren *et al.*, 2007; Delbart and Pieret, 2009).

Cost estimates of realised control measures (a combination of cutting and herbicide application), as well as direct costs for the health system, are available for Germany (Reinhardt *et al.*, 2003). The authors extrapolated that annual costs to Germany range between 6 and 21 million Euro, with the mean value of circa 12 million Euro. This total sum consists of around 1 million Euro for control in conservation areas, 2.5 million Euro for eradications along roadways and 1–2 million Euro for addressing public health issues. Costs for eradication in rural areas are estimated to start at 5.5 million Euro.

Recently, a more precise cost-benefit analysis for the eradication control of giant hogweed in Germany has been published (Rajmis *et al.*, 2017). The authors estimated minimum costs of eradication measures, including a time span of ten years and a social discount rate of 1%, which resulted in a total of 3,467,640 Euro for an optimistic scenario, and 6,254,932 Euro for a pessimistic invasion scenario, where no success of the first eradication attempt is assumed. The table below shows the estimated costs for giant hogweed eradication control using chemical treatment, and its comparison to the use of other techniques (Rajmis *et al.*, 2017).

A three year project in a heavily infested area of Western Czech Republic revealed that it is possible to lower hogweed distribution to ca. 20% (including pastures and areas where no herbicide application is allowed). The costs of such a campaign (which included management of *Fallopias* and *Impatiens glandulifera*) were 2.7 million Euro (L. Pocová, pers. comm., 2017). The methods used included application of herbicides, where allowed, and cutting in restricted areas. In Sweden, the costs for eradication of giant hogweed were calculated to be circa 1-4 SEK/m^2, but much higher along roads (100 SEK/m^2) (Gren *et al.,* 2007). This estimate is based on the total cost of control of 13 invasive species by Swedish public authorities. The total annual cost for control of giant hogweed ranges from 38,000 to 47,000 Euro.

For the UK, Sampson (1994) estimated the control cost of giant hogweed for 150 invaded sites in 1989, at between approximately 148 Euro and 42,630 Euro (historical exchange values from 2000; 1989 not available).

Additionally, southern Belgium spends circa 0.5 million Euro per year for control of giant hogweed (Pergl and Branquart, 2016).

In Denmark, about 22.5 million DKR (3 million Euro) per year are spent for control of giant hogweed. Costs of eradication are estimated to reach 45-135 million DKR/year in the first years, and then decrease to 2-8 million DKR/year after 10 years. Herbicide application had a cost of ca. 500 DKR/ha (Suadicani *et al.*, 2017).

Description of measure	Cost of labour	Cost of materials
Root destruction and mechanical cutting	33€ per hour; additional job training of 5 hours, one treatment and one after-treatment	Protective clothing, shovel, scythe, flail mower, repair cost
Chemical treatment	33€ per hour; additional job training of 5 hours, two treatments, restoration (plough and seeder, planting costs and two cuttings per year)	Protective clothing, machines, herbicide sprayer, diesel and machine oil, technical inspection agency and machine check, machine repair, glyphosate
Grazing	33€ per hour; maintenance of fencing, periodic inspection, daily inspection of animals, moving of animals between fenced area, scrub removal, branch pruning, building of stiles, supplementary cutting outside the fencing with 1,000 hours per year and administration with 15 hours per site and year	Fencing, purchase of animals, shelter, water supply, additional fodder, veterinary inspection and treatment

Source: Based on suggestions from Nielsen *et al.* (2005) and adjusted to the concrete case of eradication in the infested German districts.

Heracleum mantegazzianum. © *Zygmunt Dajdok*

Due to the limited distribution of Sosnowskyi's hogweed in Europe, most of the data on its management come from Russia and neighbouring countries. The most detailed study (Dalke *et al.*, 2018) shows that the stands of *H. sosnowskyi* were mapped on an area of 169,000 ha and were destroyed on an area of 18,000 ha. The total cost of the contracts amounted to 314 million rubles. The cost of mowing *H. sosnowskyi* was about 30,000 rubles/ha and the cost for treating thickets with herbicides was 14,500 rubles/ha (median values).

SIDE EFFECTS

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

A negative environmental side effect of using herbicides is potentially increased soil erosion, if not using selective herbicides (Pergl *et al.*, 2016), or if used in large areas. Negative effects due to residuals remaining in the soil have been discussed, but are minimal compared to agricultural land.

ACCEPTABILITY TO STAKEHOLDERS

Neutral or mixed.
Herbicide application is prohibited in organic farms, and may be controversial in urban areas and conservation sites, as after application herbicides may remain in the soil as residuals and may affect non-target species.

ADDITIONAL COST INFORMATION

Costs of eradication in various MS are listed above (see examples), as well as additional costs to public health services to treat skin burns incurred by these plants (Reinhardt *et al.*, 2003).Benefits of invasion control in Germany result in a total of 238,063,641 Euro per year (Rajmis *et al.*, 2017).

There are a few known economic benefits (besides its decorative value) resulting from the persistence of giant hogweed in invaded regions: (i) usage of giant hogweed by a limited number of beekeepers as a food supply for bees and (ii) usage as a fodder crop. In the case of fodder crop, the estimates of dry mass vary between 5.7 to 15 tonnes per ha, and the nutritional value of leaf biomass is suitable for livestock, having high organic digestibility (Buttenschon and Nielsen, 2007). For *H. sosnowskyi*, in Latvia, the estimates of maximum production reaches up to 45-80 t per hectare (Zihare and Blumberga, 2017). As such, eradication of these species would have a negative economic effect on these activities. On the other hand, in the UK, the cost incurred by giant hogweed to tourism and recreational activities is estimated as 1 million GBP per year (Williams *et al.*, 2010). Its eradication would make invaded areas accessible again for tourism and leisure activities, incurring a positive economic side effect.

LEVEL OF CONFIDENCE*

Established but incomplete.
Confidence in the methodology and effectiveness of herbicide application is documented in many published studies. On the other hand, there is a lack of information of costs for individual control methods, as most of the available studies report management per area, regardless of method. This is due to the fact that management of sites is usually based on a combination of different methods.

* See Appendix

Covering soil with plastic sheets.

MEASURE DESCRIPTION

This method has been described in a Danish report on giant hogweed (Suadicani *et al.*, 2017) and in a Russian report on *H. sosnowskyi* (Dalke and Chadin, 2008).

The method is based on using a dense plastic cover that is placed over the area with hogweeds in February-March, before massive germination. The cover has to be made from dense plastic, not light transparent, and it should be fixed to the ground to prevent any movement due to wind. Under the cover, all hogweed plants die.

SCALE OF APPLICATION

Small scale. This method is suitable for areas up to 100-200 m^2 (Suadicani *et al.*, 2017).

EFFECTIVENESS OF MEASURE

Effective.

Very effective on exposed fields (Suadicani *et al.*, 2017).

EFFORT REQUIRED

The plastic cover has to be placed at site in early spring and can be removed in August the same year.

The only problem could occur when the plastic cover is not situated in direct sun, and the temperature under the plastic might not be high enough to kill new saplings (H.P.Ravn, pers. comm.).

It is important to revegetate the managed site.

RESOURCES REQUIRED

Plastic cover, fixing material, personnel. The estimated time spent and person costs for Denmark are, respectively, 400 m^2/h and 500 KR/h (Suadicani *et al.*, 2017).

SIDE EFFECTS

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

Covering co-occurring native plants may result in their mortality, but the negative effect can be minimised by revegetation or seedbank regeneration. Similarly, covering the soil may increase soil erosion.

As the cover is placed early in the season, the risk associated with potential contact with the sap and resulting skin burnings (phytophotodermatitis) is low.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

This measure is generally acceptable to stakeholders, and suitable even for organic farmers.

ADDITIONAL COST INFORMATION

No additional information.

LEVEL OF CONFIDENCE*

Established but incomplete.

There is a report confirming the use and effectiveness of this measure on giant hogweed (Suadicani *et al.*, 2017), but further research is needed, especially on its applicability to the other hogweed species.

* See Appendix

Measures for the species' management.

Mowing (cutting) and grazing.

MEASURE DESCRIPTION

In parts of Europe, *H. sosnowskyi* has been grown as a crop for silage production (Buttenschon and Nielsen, 2007). Grazing is often applied for large areas of infestation, or for sites with restrictions on the use of herbicides (for example organic farms, protected areas). Grazing is also used in areas inaccessible for mowing machines. The plant is not toxic to animals (cows, sheep), although records of photosensitivity have been recorded (Tiley *et al.,* 1996).

SCALE OF APPLICATION

Regional scale. Grazing and mowing are effective to be applied to areas from ca. 1000 m^2 (Rajmis *et al.*, 2017). It is important that neighbouring areas of pastures invaded by giant hogweed are also managed.

EFFECTIVENESS OF MEASURE

Effective.

Mowing and grazing are not efficient methods for the eradication of hogweeds, as they prolong the age of flowering, but they are suitable for the long term management of populations and depletion of the seed bank (Caffrey, 2001; Nielsen *et al.,* 2005; Pyšek *et al.*, 2007a). Nevertheless, Buttenschon and Nielsen (2007) report that, after intensive grazing, the abundance of hogweed significantly decreases.

EFFORT REQUIRED

The text below has been taken from Pergl *et al.,* (2016):

It is necessary to start grazing/mowing early in the season, when the plants are soft (edible). For plants that flower on the ground, it is necessary to remove (usually cut by machinery) the umbels immediately when they start flowering.

Mowing and grazing should be repeated several times over a season, to avoid the formation of seeds from regenerating plants. Giant hogweed often regenerates after the first disturbance, by creating a small leaf rosette and a short (about 0.5 m) stem with a smaller inflorescence. Therefore, the subsequent cut/graze must be about 4 weeks after the first, to minimise the number of flowering plants. Both grazing and mowing need the same approach of controlling the resprouting individuals. In the case of regeneration, a complementary (third) mowing/grazing can be combined with mulching, and the regenerating plants can be dugout or cut.

If management is done later in the season (at the end of the flowering process or later), the whole inflorescence must be removed, collected in a plastic bag and safely disposed for example by burning at a suitable location. It is not possible to leave the cuttings or whole plants lying in place, because they could still develop germinating seeds. The remaining parts of the plants do not need to be cut/removed from the locality. The issue of leaving cut umbels at a site was tested in an experimental study: Pyšek *et al.,* (2007a) showed that 85% of terminal umbels cut off at the beginning of fruit formation produce some fruits (less and less viable). Additionally, Pyšek *et al.,* (2007b) also showed that it is important to remove flowering umbels from a site.

When dealing with plants with ripe seeds, it is necessary to place plastic sheets on the ground, to be able to collect the falling seeds. Such approach can be used exceptionally when discovering plants late in the season–and it leads only to a reduction of the number of seeds filling the soil seed bank at the site. It is important that such sites are monitored in the following years for potential regrowth.

The timing of the implementation of the control measure has been shown to have a significant effect to final regeneration. If the control measure is carried out too early, then fruit sets are reduced by about 50% (Caffrey, 1999). Late treatments in terms of phenological development are only effective if applied later to umbels with fruits already initiated (Otte and Franke, 1998). If the branches bearing regenerating flowering umbels are cut too early, regeneration continues.

RESOURCES REQUIRED

No special resources or machineries are needed to manage invaded areas. Mowing is not labour intensive, but protective clothes and gloves are needed to prevent contact of humans with the plant sap.

Grazing can be done by sheep, cows or other animals. The costs for grazing may include fencing.

SIDE EFFECTS

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

Heracleum mantegazzianum, Heracleum sosnowskyi, Heracleum persicum. © *Zygmunt Dajdok*

No known side effects. Effects to livestock are minimal (Department of Agriculture and Rural Development, date unknown).

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

This measure is generally acceptable by stakeholders, as hogweeds are good pasture plants, preferred by cattle and sheep (Nielsen *et al.,* 2005; www.nonnativespecies.org/downloadDocument.cfm?id=998).

ADDITIONAL COST OF INFORMATION

No additional information.

LEVEL OF CONFIDENCE*

Well established.

There is a large amount of published information dedicated to long term management of giant hogweed by mowing and grazing, as well as for Sosnowskyi's hogweed.

* See Appendix

Bibliography

Afonin, A.N., Luneva, N. N., Li, J. C., and Kocareva, N.V. (2017). Эколого-географическийанализраспространения и встречаемостиборщевика Сосновского (Heracleum sosnowskyi Manden.) в связисостепеньюарид ноститерриторий и егокартированиедляевропейскойтерритории России. Экология, 1, 66-69.

Alm, T. (2013). Ethnobotany of Heracleum persicum Desf. exFisch., an invasive species in Norway, or how plant names, uses, and other traditions evolve. *Journal of Ethnobiology and Ethnomedicine*, 9, 42.

Baležentienė, L., Stankevičienė, A., and Snieškienė V. (2014). *Heracleum sosnowskyi* (Apiaceae) seed productivity and establishment in different habitats of central Lithuania. *Ekologija*, 59, 123-133.

Branquart, E., Barvaux, C., and Büchler, E. (2011). Plan de gestion coordonné des populations d'espèces invasives en Wallonie: 1. La berce du Caucase (*Heracleum mantegazzianum*). Cellule interdépartementale Espèces invasives, Service Public de Wallonie, Gembloux, 22 pp.

Burgiel, S., Foote, G., Orellana, M., and Perrault, A. (2006). Invasive Alien Species and Trade: Integrating Prevention Measures and International Trade Rules. IUCN.

Buttenschon, R.M.,and Nielsen, C. (2007). Control of *Heracleum mantegazzianum* by grazing. In: Pyšek, P., Cock, M.J.W., Nentwig, W., Ravn, H.P. (eds.), Ecology and management of giant hogweed (*Heracleum mantegazzianum*), CAB International, pp. 240–254.

Caffrey, J.M. (1999). Phenology and control of *Heracleum mantegazzianum*. *Hydrobiologia*, 415, 223–228.

Caffrey, J.M. (2001). The management of Giant Hogweed in an Irish River Catchment. *Journal of Aquatic Plant Management*, 39, 28–33.

DAISIE (2009). Handbook of alien species in Europe. Springer, Berlin.

Dalke, I.V., and Chadin I.F. (2008). Методическиерекомендациипоборьбе с неконтролируемымраспространениемборщевикаСосновского. ПодготовленыИнститутомбиологииКоми НЦ УрО РАН позаказуМинистерствасельскогохозяйства и продовольствияРеспубликиКоми. Сыктывкар 28 с.

Dalke, I.V., Chadin, I.F., and Zakhozhiy, I.G. (2018). Анализмероприятий поликвидациинежелательныхзаростейборщевикасосновского (Heracleum sosnowskyiManden.) натерриторииРоссийскойФедерации (Control of Sosnowskyi's Hogweed (*Heracleum sosnowskyi* Manden.) Invasion on the Territory of the Russian Federation). *Russian Journal of Biological Invasions*, 9, 331-344.

Dawson, F.H., and Holland, D. (1999). The distribution in bankside habitats of three alien invasive plants in the U.K. in relation to the development of control strategies. *Hydrobiologia*, 415, 193-201.

Delbart, E., and Pieret, N. (2009). Les trois principales plantes exotiques envahissantes le long des berges des cours d'eau et plans d'eau en Région wallonne: description et conseils de gestion mécanique. *Gembloux Agro-Bio Tech*, 75 pp.

Department of Agriculture and Rural Development (date unknown). Giant hogweed (*Heracleaummantegazzianum*). Countryside management publications. http://www.nonnativespecies.org/downloadDocument.cfm?id=998.

EPPO (2009). EPPO datasheet on Invasive Alien Plants: *Heracleum mantegazzianum*, *H. sosnowskyi* and *H. persicum*. *OEPP/EPPO Bulletin*, 39, 489-499.

Eschen, R., Britton, K., Brockerhoff, E., Burgess, T., Dalley, V., Epanchin-Niell, R.S., Gupta, K., Hardy, G., *et al.*, (2015a). International variation in phytosanitary legislation and regulations governing importation of plants for planting. *Environmental Science and Policy*, 51, 228–237.

Eschen, R., Rigaux, L., Sukovata, L., Vettraino, A.M., Marzano, M., andGrégoire, J-C. (2015b). Phytosanitary inspection of woody plants for planting at European Union entry points: a practical enquiry. *Biological Invasions*, 17, 2403-2413.

FAO (2017). ISPM 41. International movement of used vehicles, machinery and equipment. IPPC and FAO.

Fried, G. (2009). Changement d'habitat d'*Heracleum mantegazzianum* (Apiaceae) au cours de son invasion en France. XIIIème Colloque international sur la biologie des mauvaises herbes, 4 pp.

Gren, I-M., Isacs, L., and Carlsson, M. (2007). Calculation of costs of alien invasive species in Sweden – technical report. Swedish University of Agricultural Sciences. Working paper series 2007, 7.

Huang, C., and Asner, G.P. (2009). Applications of remote sensing to alien invasive plant studies. *Sensors*, 9, 4869–4889.

Jahodová, S., Fröberg, L., Pyšek, P., Geltman, D., Trybush, S., and Karp, A. (2007a). Taxonomy, identification, genetic relationships and distribution of large *Heracleum* species in Europe. Ecology and management of giant hogweed (*Heracleum mantegazzianum*) In: Pyšek P., Cock M.J.W., Nentwig W. andRavn H.P. (eds.), Ecology and Management of Giant Hogweed (*Heracleum mantegazzianum*), CAB International, pp 1-19.

Jahodová,Š.,Trybush, S., Pyšek, P., Wade, M., and Karp, A. (2007b). Invasive species of *Heracleum* in Europe: an insight into genetic relationships and invasion history. *Diversity and Distributions*, 13, 99-114.

Kabuce, N., and Priede, N. (2010). NOBANIS – Invasive Alien Species Fact Sheet – *Heracleum sosnowskyi* – From: Online Database of the European Network on Invasive Alien Species – NOBANIS, www.nobanis.org, Date of access: April 2019.

Moravcová, L., Gudžinskas, Z., Pyšek, P., Pergl J., andPerglová, I. (2007b). Seed ecology of *Heracleum mantegazzianum* and *H. sosnowskyi*, two invasive species with different distributions in Europe. In: Pyšek P., Cock M.J.W., Nentwig W. andRavn H.P. (eds.), Ecology and Management of Giant Hogweed (*Heracleum mantegazzianum*), CAB International, pp 157-169.

Moravcová, L., Pyšek, P., Krinke, L., Pergl, J., Perglová, I., and Thompson, K. (2007a). Seed germination, dispersal and seed bank in *Heracleum mantegazzianum*. In: Pyšek, P., Cock, M.J.W., Nentwig, W., Ravn, H.P. (eds.), Ecology and management of giant hogweed (*Heracleum mantegazzianum*), CAB International, pp 74–91.

Moravcová, L., Pyšek, P., Pergl, J., Perglová, I., and Jarošík, V. (2006). Seasonal pattern of germination and seed longevity in the invasive species *Heracleum mantegazzianum*. *Preslia*, 78, 287–301.

Muller, S. (2004). Plantes invasives en France: état des connaissances et propositions d'actions. Publication scientifique du Museum d'Histoire Naturelle, Patrimoines naturels, 62.

Müllerová, J., Brůna, J., Bartaloš, T., Dvořák, P., Vítková, M., and Pyšek, P. (2017). Timing is important: unmanned aircraft versus satellite imagery in plant invasion monitoring. *Frontiers in Plant Science*, 8, 887.

Müllerová, J., Pergl, J., and Pyšek, P. (2013). Remote sensing as a tool for monitoring plant invasions: testing the effects of data resolution and image classification approach on the detection of a model plant species *Heracleum mantegazzianum* (giant hogweed). *International Journal of Applied Earth Observation and Geoinformation*, 25, 55–65.

Müllerová, J., Pyšek, P., Jarošík, V., and Pergl, J. (2005). Aerial photographs as a tool for assessing the regional dynamics of the invasive plant species *Heracleum mantegazzianum*. *Journal of Applied Ecology*, 42, 1042–1053.

Nielsen, C., Ravn, H.P., Cock, M., and Nentwig, W. (eds.) (2005). The giant hogweed best practice manual. Guidelines for the management and control of an invasive alien weed in Europe. Forest and Landscape Denmark, Hoersholm, Denmark.

NOBANIS (2015). The European Network on Invasive Alien Species (NOBANIS). www.nobanis.org, Accessed November 2015.

Otte, A., and Franke, R. (1998). The ecology of the Caucasian herbaceous perennial *Heracleum mantegazzianum*Somm. et Lev. (Giant Hogweed) in cultural ecosystems of Central Europe. *Phytocoenologia*, 28, 205–232.

Panetta, F.D., and Timmins, S.M. (2004). Evaluating the feasibility of eradication for terrestrial weed incursions. *Plant Protection Quarterly*, 19(1), 5-11.

Pergl, J., and Branquart, E. (2016). *Heracleum mantegazzianum*, Risk Assessment. https://circabc.europa.eu/sd/a/5e1a5da5-b5b3-4f47-bdbd-a04e4a75acac/Heracleum%20mantegazzianum%20RA.doc.

Pergl, J., Perglová, I., Vítková, M., Pocová, L., Janata, T., and Šíma, J. (2016). Likvidace vybraných invazních druhů rostlin; Standardy péče o přírodu a krajinu. AOPK ČR.

Pergl, J., Pyšek, P., Perglová, I., and Jarošík, V. (2012). Low persistence of a monocarpic invasive plant in historical sites biases our perception of its actual distribution. *Journal of Biogeography*, 39, 1293–1302.

Perglová, I., Pergl, J., and Pyšek, P. (2006). Flowering phenology and reproductive effort of the invasive alien plant *Heracleum mantegazzianum*. *Preslia*, 78, 265–285.

Pluess, T., Cannon, R., Jarošík, V., Pergl, J., Pyšek, P., and Bacher, S. (2012). When are eradication campaigns successful? A test of common assumptions. *Biological Invasions*, 14, 1365–1378.

Pyšek, P., Chytrý, M., Pergl, J., Sádlo, J., and Wild, J. (2012). Plant invasions in the Czech Republic: current state, introduction dynamics, invasive species and invaded habitats. *Preslia*, 84, 576–630.

Pyšek, P., Cock, M.J.W., Nentwig, W., and Ravn, H.P. (2007a). Master of all traits: can we successfully fight giant hogweed? In: Pyšek, P., Cock, M.J.W., Nentwig, W., Ravn, H.P. (eds.), Ecology and management of giant hogweed (*Heracleum mantegazzianum*), CAB International, pp. 297–312.

Pyšek, P., Genovesi, P., Pergl, J., Monaco, A., and Wild, J. (2013). Plant invasions of protected areas in Europe: an old continent facing new problems. In: Foxcroft, L.C., Pyšek, P., Richardson, D.M.,Genovesi, P. (eds.), Plant invasions in protected areas: patterns, problems and challenges, Springer, Dordrecht, pp. 209–240.

Pyšek, P., Jarošík, V., Müllerová, J., Pergl, J., and Wild, J. (2008). Comparing the rate of invasion by *Heracleum mantegazzianum* at continental, regional, and local scales. *Diversity and Distributions*, 14, 355–363.

Pyšek, P., Perglová, I., Krinke, L., Jarošík, V., Pergl, J., and Moravcová, L. (2007b). Regeneration ability of *Heracleum mantegazzianum* and implications for control. In: Pyšek, P., Cock, M.J.W., Nentwig, W., Ravn, H.P. (eds.), Ecology and management of giant hogweed (*Heracleum mantegazzianum*), CAB International, pp. 112–125.

Rajmis, S., Thiele, J.,and Marggraf, R. (2017). A cost-benefit analysis of controlling giant hogweed (*Heracleum mantegazzianum*) in Germany using a choice experiment approach. *NeoBiota*, 31, 19–41.

Reinhardt, F., Herle, M., Bastiansen, F., and Streit, B. (2003). Economic impact of the spread of alien species in Germany. Report No. UBA-FB. Biological and Computer Sciences Division, Dept. of Ecology and Evolution, Frankfurt am Main, Germany.

Sampson, C. (1994). Cost and impact of current control methodsused against *Heracleum mantegazzianum* (Giant Hogweed) and the case for instigating a biological control programme. In: deWaal, L., Child, L., Wade, M., Brock, J. (eds.), Ecology andManagement of Invasive Riverside Plants. John Wiley and Sons,Chichester, pp. 55–66.

Seier, M., and Evans, H.C. (2007). Fungal pathogens associated with *Heracleum mantegazzianum* in its native and invaded distribution range. In: Pyšek, P., Cock, M.J.W., Nentwig, W., Ravn, H.P. (eds.), Ecology and management of giant hogweed (*Heracleum mantegazzianum*), CAB International, pp. 189–208.

Suadicani, K., Buttenschøn, R.M., Ravn, H.P., and Johannsen V.K. (2017). Kæmpe-bjørneklo i Danmark – status for bekæmpelsen. Udbredelse og indsats, de anvendte metoder og deres effekt samt en analyse af samfundsøkonomien i forbindelse med bekæmpelsen. IGN, Frederiksberg. 55 s.

Thiele, J., and Otte, A. (2006). Analysis of habitats and communities invaded by *Heracleum mantegazzianum*Somm. et Lev. (Giant Hogweed) in Germany.*Phytocoenologia*, 36(2), 281-320.

Thiele, J., Otte, A., and Eckstein, R.L. (2007). Ecological needs, habitat preferences and plant communities invaded by *Heracleum mantegazzianum*. In: Pyšek, P., Cock, M.J.W., Nentwig, W., Ravn, H.P. (eds.), Ecology and management of giant hogweed (*Heracleum mantegazzianum*), CAB International, pp. 126–143.

Tiley, G.E.D., Dodd, F.S., and Wade, P.M. (1996).*Heracleum mantegazzianum* Sommier and Levier. *Journal of Ecology*, 84, 297–319.

Tiley, G.E.D., and Philp, B. (1997). Observations on flowering and seed production in *Heracleum mantegazzianum* in relation to control. In: Brock, J.H., Wade, M., Pyšek, P. and Green D. (eds.) Plant Invasions: Studies from North America and Europe. Backhuys Publishers, Leiden, The Netherlands, pp. 123–137.

Wadsworth, R.A., Collingham, Y.C., Willis, S.G., Huntley, B., and Hulme, P.E. (2000). Simulating the spread and management of alien riparian weeds: are they out of control? *Journal of Applied Ecology*, 37(1), 28-38.

Williams, F., Eschen, R., Harris, A., Djeddour, D., Pratt, C., Shaw, R.S., Varia, S., Lamontagne-Godwin, J., Thomas, S.E., and Murphy, S.T. (2010). The Economic Cost of Invasive Non-Native Species on Great Britain. CABI, 197 pp.

Zihare, L., and Blumberga, D. (2017). Invasive species application in bioeconomy. Case study *Heracleum sosnowskyi* Manden in Latvia. *Energy Procedia*, 113, 238-243.

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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