Information on measures and related costs in relation to species included on the Union list

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This technical note provides information on the effectiveness of measures, alongside the required effort and resources, used to prevent the introduction, and to undertake early detection, rapid eradication, and management for the invasive alien species under review. Each table represents a separate measure.

Species (scientific name)	*Heracleum mantegazzianum* Sommier & Levier
Species (common name)	Giant hogweed
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Summary

Highlight of measures that provide the most cost-effective options to prevent the introduction, achieve early detection, rapidly eradicate and manage the species, including significant gaps in information or knowledge to identify cost-effective measures.

Prevention

Giant hogweed (*Heracleum mantegazzianum*) is already widely established in many countries in Europe (DAISIE, 2009; Nobanis, 2015). Secondary spread of the species, via unintentional transport of seeds, e.g. via contaminated soils, is the most important likely pathway that needs to be addressed to prevent new introductions of the species. 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 minimize the risk of the transport of seeds to areas and countries where the species is not yet established. In addition, a ban on keeping, importing, selling, breeding and growing of giant hogweed seeds as required under Article 7 of the IAS Regulation will address the intentional spread and introduction of the species for horticultural purposes.

Early detection

The priority for early detection to allow for rapid eradication of the species 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

The only effective way currently known to eradicate the species is through the use of herbicides and the removal of rootstock by digging to about 5-15 cm below the ground under the root (Pyšek *et al.,* 2007d). Mowing and grazing is not an efficient method to eradicate the species (Caffrey, 2001; Nielsen *et al*., 2005; Pyšek *et al*., 2007b), and there is no efficient biocontrol known in Europe (Pyšek *et al*. 2007b; Seier and Evans, 2007). Due to good detectability of the plant prior to reproduction (due to its large size), absence of spread by vegetative fragments and high effectiveness of control techniques, its eradication may be easily achieved when the eradication management is maintained over a period of several years (circa up to 10 years) (www.nonnativespecies.org/downloadDocument.cfm?id=998). Strategies required to achieve eradication can be divided along the scale of the infested area (see Nielsen *et al.,* 2005; Pergl *et al.*, 2016a; Rajmis *et al.,* 2017, Table 1) 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 giant hogweed are relevant for the management of eradication actions:

- Giant hogweed can reproduce only by seed.
- Giant hogweed reproduces only once and dies after setting seeds.
- The species has short term persistent seed-bank; the majority of seeds germinates within the first or second year.
- Giant hogweed is species with extremely high potential for regeneration.
- The species is sensitive to wide range of herbicides.

Overall, management should target the unintentional spread of seeds by transportation of contaminated soil or machinery. If total eradication is not

feasible (due to lack of resources), the seed production needs to be limited, and any management needs to be planned systematically (i.e. to prioritize remote sites, begin management action 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 minimizing the risk of seed production and transportation (Pyšek *et al.,* 2007d). The species has short term persistence in soil seed-banks, with the majority of seeds germinating in the first and second year (Moravcová *et al.,* 2006, 2007). Nevertheless, a small proportion of seeds are able to survive for up to 7 years (Moravcová *et al.,* 2007), requiring any management of giant hogweed stands to be monitored in the medium term.

Since the species dies after flowering, it can be distinguished between the control of the 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 (e.g. 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 (Pyšek *et al*., 2007d). Giant hogweed is a species with an extremely high regeneration ability, as flowering plants can re-sprout after damage and set seed within one month (Pyšek *et al.*, 2007d).

If a long-term programme is feasible (circa 10 years), only flowering plants need to be targeted until the population is depleted. For the mechanical control of large populations, grazing and cutting/mowing may help to reduce the size of populations, however timing of the measures is crucial as if these measures 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, in buffer areas of water resources or within protected areas.

Summary following Pyšek *et al*. (2007d):

1. The only treatment that effectively kills giant hogweed plants is the destruction of the tap root at 15 cm depth below-ground, or the application of herbicides.
2. Timing of the treatment is crucial. If carried out too early, individuals will regenerate successfully.
3. The life stage of the targeted plants for control needs to be taken into account when planning the management. If a long-term management is feasible, only flowering plants 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 (e.g. extent or budget restrictions), reducing the number of seeds produced is important.

Prevention – 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. **This table is repeated for each of the prevention measures identified.**	
Measure description Provide a description of the measure	**Biosecurity measures to prevent unintentional introduction through transportation of seeds** Giant hogweed (*Heracleum mantegazzianum)* is already widely established throughout Europe (DAISIE, 2009;

	Nobanis, 2015) and the *unintentional* secondary spread of the species within Europe, e.g. via contaminated soil, is the most important likely pathway of introduction that needs to be addressed. Currently, there are no known intentional or unintentional introductions from the region of origin, the western Caucasus (or at very low probability and volume) (Pergl and Branquart, 2016). In the case of giant hogweed, secondary spread within the European Union is likely to be much more important than introductions unintentionally from outside regions of the EU. The species reproduces only by seeds, so management of the reproduction stage and minimizing the seed production and transport is crucial (Pyšek *et al.,* 2007d). Soil as a commodity, or a contaminant, have been identified as relevant introduction pathways for other invasive *Heracleum* species - see EPPO Pest Risk Analysis for *H. sosnowskyi* and *H. persicum* (EPPO, 2009; www.eppo.int). These measures would need to include the checking of clothes, equipment and vehicles for giant hogweed seeds when leaving a contaminated sites. Linear rate of expansion of giant hogweed at regional scale is between 4 and 30 m/year (Müllerová *et al*., 2005), however, the distance of seed dispersal by water can reach more than 10 km (Wadsworth *et al*., 2000; Moravcová *et al*., 2010; see experiment in Trottier *et al.*, 2017). The spread of seeds by wind and water from populations occurring along water courses and transport corridors, is very frequent (Pyšek and Pyšek, 1995; Thiele *et al.*, 2007; Pergl *et al*. 2012). These measures need to be closely integrated with awareness raising activities (see table below).
Effectiveness of measure e.g. has the measure previously worked, failed	**Effective**, if applied comprehensively at contaminated sites as the species reproduces only by seeds.
Effort required e.g. period of time over which measure need to be applied to have results	The measures need to be applied in the long term until the populations at the contaminated sites have been eradicated, and for up to 7 years post eradication as a small proportion of seeds are able to survive for up to 7 years in the seed bank (Moravcová *et al.,* 2007).
Resources required [1] e.g. cost, staff, equipment etc.	Not special resources are needed, beyond staff time for cleaning and checking equipment etc. For cleaning the equipment no special chemical treatment is required.
Side effects (incl. potential) i.e. positive or negative side effects of the measure on public health, environment, non-targeted species, etc.	There are no expected negative side effects for proposed measures.

Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	If the measures are adopted alongside awareness raising activities, conflicts with stakeholders are not expected. The proposed measures are not expensive or time consuming to undertake.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	There is no cost information available for the implementation of these measures, however no additional costs are expected. Further spread of the species to areas where it is not already present followed by eradication can be significant (see below details on different methods; the cost of inaction).
Level of confidence [2] See guidance section	**Medium –** there are not exact info about the international trade and spread of the species across borders. Local spread is well described by several studies (e.g. Pergl *et al.* 2012). Based on expert knowledge, the effectiveness of the implementation prevention is high, but there is lack of direct studies on giant hogweed.

Prevention – 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. **This table is repeated for each of the prevention measures identified.**	
Measure description Provide a description of the measure	**A ban on keeping, importing, selling, breeding and growing as required under Article 7 of the IAS Regulation and awareness raising (intentional spread)** The species is already widely established throughout Europe, and human activities are known as the significant component for the species spread (Pergl *et al.,* 2012). Giant hogweed is listed in several national invasive species 'black lists' (e.g. EPPO 2009; Nehring *et al*., 2013; Weber, 2013; Pergl *et al*., 2016b) and although public awareness has increased (Nielsen *et al.,* 2005), the horticultural use for ornamental purposes is still common (Pergl *et al*., 2012, 2016a). As giant hogweed can spread very rapidly (Wadsworth *et al.* 2000; Müllerová *et al.* 2005; Moravcová *et al.* 2010) along water courses and transport corridors (Pyšek and Pyšek 1995; Thiele *et al.* 2007; Pergl *et al.* 2012), it is important to stop using it as an ornamental plant in gardens as it is able to easily colonise new sites in the vicinity of already existing stands (Thiele *et al.* 2007; Pergl *et al.* 2012). Therefore an important preventative measure needed is to stop the *intentional* spread of the species via horticultural trade. This can only be achieved through the banning of the import/selling/growing/keeping of the

	species (restrictions as per Article 7. of the EU Invasive Alien Species Regulation), alongside awareness raising particularly focusing on online retailers of seeds and peer-to-peer selling (e.g. see continued selling of the congener *H. sosnowskyi* - http://www.plant-world-seeds.com/store/view_seed_item/732). There are many existing publications to support engagement with horticultural sector and public. The species is described in many popular books e.g. Nentwig (2010, 2012), in field guidebooks devoted to amateur botanists interested in alien species (see Weber, 2013; Booy *et al.,* 2015), practically oriented guidebooks (see Nielsen *et al.,* 2005; Booy and Wade 2007), and more scientifically focused publications (see Pyšek *et al.*, 2007a). The guidebook by Nielsen *et al.* (2005) is available in seven languages and is a practically oriented manual for management and is a result of an EU project devoted to giant hogweed. There are also plenty of web pages describing the ecology and risks of giant hogweed invasion (e.g. www.nonnativespecies.org, www.nobanis.org, and http://www.invasivespeciesscotland.org.uk/giant-hogweed-heracleum-mantegazzianum/).
Effectiveness of measure e.g. has the measure previously worked, failed	There are no examples or experiences of banning this species from trade. However, as it occurs mainly as a result of former plantings or in neighbouring areas (Pergl *et al.* 2012), the restrictions including banning trade etc. is believed to be a highly effective measure to reduce the intentional spread of the species to Member States and areas where it is not yet found.
Effort required e.g. period of time over which measure need to be applied to have results	A ban on keeping, importing, selling, breeding and growing is required under Article 7 of the IAS Regulation. Listing the species enforces the ban of intentional selling and importing of seeds particularly through online shops. In terms of awareness raising there are already plenty of information brochures and books, or so called codes of conduct for horticulture or botanical gardens that exist in many national languages. Hogweeds are a common invasive alien species and therefore are covered by many ongoing information campaigns (e.g. see LIFE Wetlands – conservation and management of priority wetland habitats in Lithuania LIFE13 NAT/LV/000578; and http://ec.europa.eu/environment/life/publications/lifepublications/lifefocus/documents/life_ias.pdf).
Resources required [1] e.g. cost, staff, equipment etc.	No extra resources required for enforcing a ban (particularly for online retailers and peer-to-peer trade) beyond what is already being established by Member States under the EU Invasive Alien Species Regulation. In terms of awareness raising there are many established projects and publications (see above).
Side effects (incl. potential) i.e. positive or negative side effects of the measure on public health, environment, non-targeted species, etc.	There are no expected negative side effects for proposed measures. Positive effect is, that giant hogweed is widely recognized invasive species so it can be used as “flag ship” for the eradication campaigns.
Acceptability to stakeholders	While seed providers may be impacted by a ban in the import/selling of the species, the horticultural sector is

e.g. impacted economic activities, animal welfare considerations, public perception, etc.	generally well informed on the impacts of giant hogweed, and therefore is not expected to provide any significant conflict. In addition the direct costs to sellers are not expected to be high as the species is rarely sold.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	There is no information on costs for this measure. No significant additional costs are expected, apart from enforcing and monitoring a ban. However, mechanisms that are put in place by Member States to monitor and enforce the restrictions put in place on other invasive alien species of Union concern can be adopted for giant hogweed. Without adequate management, which includes banning of trade etc., to prevent intentional introduction of the species to new localities within Europe, giant hogweed has a high potential for further spread in Europe. It could colonize the few uninvaded EU member states and significantly increase its population density in the already invaded countries as it has highly dynamic pattern of distribution (Pergl *et al*. 2012).
Level of confidence [2] See guidance section	**Medium.** The medium confidence was selected as the above listed statements are documented by references, but exact cost estimates are missing. Based on expert knowledge, the effectiveness of the implementation prevention can be high, but there is lack of direct studies on giant hogweed.

Early detection - Measures to achieve early detection and run an effective surveillance system for achieving an early detection of a new occurrence (cf. Article 16 of the IAS Regulation). This section assumes that the species is not currently present in a Member State, or part of a Member State's territory. **This table is repeated for each of the early detection measures identified.**	
Measure description Provide a description of the surveillance method	**Reporting of new occurrences through 'citizen science' and active monitoring of high risk sites** Early detection of giant hogweed relies upon the reporting of new occurrences through 'citizen science' and the active monitoring of high risk sites. Giant hogweed colonizes easily new sites in vicinity of already existing stands (Thiele *et al.* 2007; Pergl *et al.* 2012), but can be limited in areas where the plant recently established (e.g. Belgium, France or Slovenia) compared to areas where it has established long time ago (e.g. Czech Republic, Baltic countries and Germany) (Muller 2004; Thiele & Otte 2006; Fried 2009; Branquart *et al.* 2011; Pyšek *et al.* 2008; Pyšek *et al.* 2012).

	The identification of new occurrences through citizen science, and the general public, is supported by awareness raising activities. In sites where the occurrence of the species can be expected, e.g. neighbouring areas to existing infestations, expert field surveys and the use of remote sensing data (UAV, aerial photos) can be used for early detection (Müllerová *et al*. 2013, 2017). Remote sensing (RS) has been was proved to be useful for monitoring shrubs and trees (Huang and Asner 2009).
Effectiveness of the surveillance e.g. has the surveillance previously worked, failed	The species flowers 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 recognizable on satellite data of coarser spatial resolution (Rapid Eye) (Müllerová *et al.,* 2017). For herbaceous species using remote sensing (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. Using remote sensing (RS) is less costly than the direct mapping in the field but is limited that only flowering individuals at open habitats can be recorded. However, while RS detection of flowering individuals is relatively easy, that of fruiting or non-flowering plants is limited, and the data capturing the species in the fruiting period (1973 panchromatic and 1987 multispectral aerial photography) show significantly lower recognition success (Müllerová *et al.* 2017). Fruiting plants without flowering umbels were not well separable from the surrounding vegetation; its 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 the aerial photographs. RS by drones is limited to areas where UAV can be used (e.g. areas outside urban zones, roads). Expert field surveys are highly effective (Pocová *et al.* pers. comm., Pergl *et al.,* 2012), but in terms of citizen science and public identification, even though the species is the tallest herbaceous plant in Europe and has an exotic appearance, the reporting of new locations e.g. through smartphone applications (e.g. 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.
Effort required e.g. required intensity of surveillance (in time and	For RS and field surveys the target areas need to be identified in advance by preliminary reports of occurrence (e.g. through Natura 2000 sites), which may allow costs, and the efficiency of mapping,

space) to be sufficiently rapid to allow rapid eradication	to be estimated. The time needed for field mapping is comparable for other surveys like Natura 2000. For RS it is crucial to monitor the sites during the appropriate time, as only certain phenological stages (flowering and early fruiting) are distinct enough to be accurately distinguished. For citizen science, the effort required will be with the 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).
Resources required [1] e.g. cost, staff, equipment etc.	Citizen science and available mobile phone applications devoted to recording the species may need to be developed (though many already exist – see above), and the resulting distribution data should be linked directly to national agencies responsible for dealing with alien species. The agencies after verifying the records should forward the reports to EU early warning system. Direct field surveys can be informed using preliminary data (e.g. Natura 2000, citizen science, national or regional plant inventories) which is relatively cheap (ca 1 Euro per ha, Pocová, pers. comm.). Non targeted field surveys can be part of other established monitoring programmes e.g. for Natura 2000 sites. Giant hogweed is a species that can be easily identified and reported. The resources needed for RS depend if the photographs have to be taken or if the analysis is based on existing data. For RS aerial photographs or detailed satellite data are needed. If the area to be monitored is relatively small, than using drones is recommended due to flexibility in area monitored, time restrictions and speed at which survey can be undertaken relative to the area covered. The estimate of the costs for satellite photos range between 20 Euro (satellite Pleiades) to 30 Euro (satellite WorldView-2) (Müllerová, pers. comm.). The problem with satellite data is in low flexibility and dependence on weather (occurrence of clouds).
Side effects (incl. potential) i.e. positive or negative side effects of the method on public health, environment, non-targeted species, etc.	As the plants sap can burn human skin (phytophotodermatitis), any public engagement to support the identification of new sites of the species needs to include clear warnings not to handle the plant.
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	Direct field surveys can be problematic in private properties, it is important that access to private land is granted by land managers and landowners. Use of drones also may generate public opposition.
Additional cost information [1] When not already included above, or in the species Risk	Most of the EU Member States already have some information systems for collating biodiversity data that are accessible for the public to submit records, therefore no extra costs for developing

Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	the software environment are expected unless smartphone applications are desired.
Level of confidence [2] See guidance section	**High.** There are studies focused on giant hogweed recognition from aerial photos with detailed description and wide range of approaches so confidence was proposed to be high.

Rapid eradication - Measures to achieve rapid eradication after an early detection of a new occurrence (cf. Article 17). This section assumes that the species is not currently present in a Member State, or part of a Member State's territory. **This table is repeated for each of the eradication measures identified.**	
Measure description Provide a description of the measure	**Herbicide application** Rapid eradication of small populations is undertaken relatively easily by root cutting, or by use of herbicides, however eradication of large infestations can be problematic (Wadsworth *et al*., 2000; Pluess *et al*., 2012; Pergl *et al*., 2016a). Based on data from the Czech Republic the ability to eradicate small populations of giant hogweed is high (Pergl *et al.,* 2016a) Giant hogweed is sensitive to a wide range of herbicides (e.g. active component glyphosate, triclopyr) (www.nonnativespecies.org/downloadDocument.cfm?id=998). We recommend the use of selective herbicides, so that the invaded area can be quickly overgrown with grasses which suppress young hogweed plants and prevents 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. Injections into stems and roots is recommended only in highly sensitive areas such nature valued habitats. EU/national/local legislation on the use of plant protection products and biocides needs to be respected.
Effectiveness of measure e.g. has the measure previously worked, failed	**Highly effective** – target plants do not survive, and if the herbicide is applied in right time (May), seeds are not produced (Pyšek *et al.* 2007d). In table 1 are summarized different approaches and suitability of application depending the size of infestation. Recent study from Denmark recommended root cutting even to population sizes up to 10 000 individuals (Suadicani *et al.,* 2017).

Table 1 – Methods of suitable giant hogweed management. Taken from Rajmis *et al.* (2017).

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 m²)	X	-	-	X	-	-
Medium (>100–1000 m²)	-	X	-	X	-	X
Large (>1000 m²)	-	-	X	-	X	X

Effort required
e.g. period of time over which measure need to be applied to achieve rapid eradication

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 0.5 m high. The spraying of herbicides should also be applied before the plants begin to form a flowering stem. After this time 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.,* 2016a). Injection of herbicides to 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 (www.nonnativespecies.org/downloadDocument.cfm?id=998).

Resources required [1]
e.g. cost, staff, equipment etc.

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

The species is in the top ten of IAS species in Europe (Pyšek *et al.* 2013; DAISIE, 2015) because the risk of human injuries (phytophotodermatitis), high rate of spread and its impact on biodiversity, and therefore there is significant funds invested into its eradication (in many cases the eradication costs include also campaigns on other IAS). The eradication costs of dense populations of giant hogweed are between 1,000 and 50,000 EUR/ha/year depending on control technique (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).

The estimates of direct costs on health system and costs of realized control measures are available for Germany (Reinhardt *et al.,* 2003). They extrapolated annual costs to Germany range between 6-

21 million Euro, with the mean value of circa 12 million Euro. This total sum consists of 1–2 million Euro for public health, 1 million Euro in conservation areas and 2.5 million Euro for eradications along roadways. Costs for eradication in rural areas are estimated to start at 5.5 million Euro.

Recently more precise estimate of cost-benefit analysis of control of giant hogweed in Germany is available from Rajmis *et al.* (2017). They 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. Based on their numbers, benefits of invasion control in Germany result in a total of 238,063,641 Euro per year.

Fig 2. Costs of giant hogweed control in Germany. Taken from Rajmis *et al.* (2017).

Description of measure	Cost of labor	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.

In addition, a three year project in a heavily infested area of Western Czech Republic revealed that it

	is possible to lower its 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.). In Sweden, the costs for eradication of the species were calculated to be circa 1-4 SEK/m2, but much higher along roads (100 SEK/m2) (Gren *et al.,* 2007). This estimate is based on the total cost of control of 13 invasive species by Swedish public authorities and they estimate for them total annual cost between 153 million Euro and 479 million Euro. The total annual cost for giant hogweed control range 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 is spend about 22.5 mill DKR (3 mill Euro) per year for control of giant hogweed. Costs of eradication are estimated to reach 45-135 mill DKR/year in the first years and then decreased to 2-8 mill after 10 years (Suadicani *et al.*, 2017).
Side effects (incl. potential) i.e. positive or negative side effects of the measure on public health, environment, non-targeted species, etc.	In large areas with restrictions on the use of herbicides (e.g. organic farms, protected areas) only mechanical methods are allowed (Pergl *et al.* 2016a). The use of herbicides in environmentally sensitive sites can be addressed by the use of injection of herbicides to the stem. The economic costs and benefits associated with the invasion (not the costs of eradication) of giant hogweed are rarely documented. There are a few known benefits (besides its decorative value) resulting from the persistence of giant hogweed in the invaded regions: (i) usage of giant hogweed by limited number of beekeepers as a food supply for bees and (ii) 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 reach up to 45- 80 t per hectare (Zihare and Blumberga 2017). Giant hogweed may also limit tourism and leisure activities due to the areas made inaccessible; in the UK, the cost incurred by tourism and recreational activities is estimated as 1 million GBP per year (Williams *et al.* 2010).

Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	Herbicide application is problematic in organic farms, urban areas and conservation sites. EU/national/local legislation on the use of plant protection products and biocides needs to be respected.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	Additional costs in various MS are listed above, for example the cost of 1–2 million Euro/year to public health services to treat skin burns (Reinhardt *et al.*, 2003).
Level of confidence [2] See guidance section	**High** confidence of effectiveness of herbicide application is documented in many published studies confirming its use and the costs needed.

Rapid eradication - Measures to achieve rapid eradication after an early detection of a new occurrence (cf. Article 17). This section assumes that the species is not currently present in a Member State, or part of a Member State's territory. **This table is repeated for each of the eradication measures identified.**	
Measure description Provide a description of the measure	**Digging out the roots (root cutting)** Digging out the roots is the only mechanical method that immediately destroys giant hogweed (Tiley and Philp, 1997; www.nonnativespecies.org/downloadDocument.cfm?id=998). Root cutting can be applied to areas with relatively low coverage, and areas up to approximately 500 m^2. 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 sites the roots need to be removed from the site or placed on the foliage of the up-rooted plants without soil contact. 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 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.,* 2016a).
Effectiveness of measure e.g. has the measure previously worked, failed	**Very effective** if done properly (Tiley and Philp, 1997; Rajmis *et al.*, 2017). Suitable for relatively small areas (circa 500 m^2) (Rajmis *et al.,* 2017). Cutting the tap root as a method for eradicating the plant comes from Tiley and Philp (1997), who studied the effect of cutting at different root depths and

	stem heights on regeneration. They found that cutting the plants 5 cm below the soil surface or at ground level allowed re-growth of shoots from axillary buds below ground. Such observation is in concordance with Caffrey (1999) where no mortality was recorded among plants cut to ground level.
Effort required e.g. period of time over which measure need to be applied to achieve rapid eradication	The best time of the year to undertake the root digging is at the beginning of the growing season (April to June) in order to avoid problematic handling with flowering plants. Although the method is effective throughout the year, must be done at the very beginning of the fruiting season, before the seeds are released. No need to repeat the management for the correctly treated plants, but necessary to revisit the localities to manage overlooked individuals, regenerating plants and plants germinated from the soil seed bank (the same year as well as following years, minimum for seven years).
Resources required [1] e.g. cost, staff, equipment etc.	Not special resources are needed. Only the labour, and digging and protection equipment (e.g. gloves) is required. See table above for estimates of costs in Germany.
Side effects (incl. potential) i.e. positive or negative side effects of the measure on public health, environment, non-targeted species, etc.	The only risk associated with this method is potential contact with the sap and the skin burnings (phytophotodermatitis). Therefore it is essential to wear protective clothes.
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	Suitable even for organic farmers.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	No additional costs identified.
Level of confidence [2] See guidance section	**High.** There are a number of published studies confirming its use and effectiveness.

Rapid eradication - Measures to achieve rapid eradication after an early detection of a new occurrence (cf. Article 17). This section assumes that the species is not currently present in a Member State, or part of a Member State's territory. **This table is repeated for each of the eradication measures identified.**	
Measure description Provide a description of the measure	**Covering soil with the plastic sheets.** Method that was described in a Danish report on giant hogweed (Suadicani *et al.*, 2017). Method is based on using a dense plastic cover that is placed over the area with hogweeds in Feb-March before massive germination. Under the cover all hog weed plants die. Method is suitable for areas up to 100-200 m^2.
Effectiveness of measure e.g. has the measure previously worked, failed	**Very effective** (Suadicani *et al.*, 2017).
Effort required e.g. period of time over which measure need to be applied to achieve rapid eradication	The cover has to be placed at site in early spring. The cover has to be from dense plastic not light transparent. The plastic could be removed in August same year. It is important to revegetate the managed site. It is important to fix the cover on the ground to prevent any movement due to wind.
Resources required [1] e.g. cost, staff, equipment etc.	Plastic cover, fixing material. The estimated time and person costs for Denmark are 400 m2 per hour.
Side effects (incl. potential) i.e. positive or negative side effects of the measure on public health, environment, non-targeted species, etc.	As the cover is placed early in the season, the risk associated with potential contact with the sap and the skin burnings (phytophotodermatitis) is low.
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	Suitable even for organic farmers.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	No additional costs identified.
Level of confidence [2]	**High.** Based on the report (Suadicani *et al.*, 2017) confirming its use and effectiveness.

See guidance section	

Management - Measures to achieve management (cf. Article 19). This section assumes that the species is already established in a Member State, or part of a Member State's territory. **This table is repeated for each of the management measures identified.**	
Measure description Provide a description of the measure	**Mowing (cutting) and grazing.** Often applied for large areas of infestation, or for sites with restrictions on the use of herbicides (e.g. organic farms, protected areas). Grazing is used in areas inaccessible for mowing machines. The plant is not toxic to animals (cows, sheep), however records of photosensitivity is recorded (Tiley *et al.,* 1996).
Effectiveness of measure e.g. has the measure previously worked, failed	Mowing and grazing are not efficient methods for the eradication of giant hogweed as they only 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.*, 2007b).
Effort required e.g. period of time over which measure need to be applied to have results	Taken from Pergl *et al.* (2016a). 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 flower. 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 following cut/graze must follow about 4 weeks after the first to minimize the number of flowering plants. Both grazing and mowing needs the same approach of controlling the resprouting individuals. In the case of regeneration, a complementary (third) mowing/grazing can be combined with the mulch and the regenerating plants can be dug out 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 e.g. 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 experimental

	study. Pyšek *et al.* (2006) 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.* (2007d) showed that it is important remove flowering umbels from a site. When dealing with plants with ripe seeds, it is necessary to place the plastic on the ground to be able 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 control had significant effect to final regeneration. If the control measure is carried out too early, than 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, the regeneration continues.
Resources required [1] e.g. cost, staff, equipment etc.	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 (incl. potential) i.e. positive or negative side effects of the measure on public health, environment, non-targeted species, etc.	No known side effects. Effects to livestock are minimal (Department of Agriculture and Rural Development, date unknown). It is important to manage also neighbouring areas of the pastures if invaded by giant hogweed.
Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.	Suitable. Giant hogweed is good pasture plant preferred by cattle and sheep (Nielsen *et al.,* 2005; www.nonnativespecies.org/downloadDocument.cfm?id=998).
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	There are no additional cost information available.
Level of confidence [2] See guidance section	**High.** There is a large amount of published information dedicated to long term management of giant hogweed by mowing and grazing.

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Notes

1. Costs information. The cost information depends on the information available.

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

- **High**: Information comes from published material, or current practices based on expert experience applied in one of the EU countries or third country with similar environmental, economic and social conditions.
- **Medium**: Information comes from published data or expert opinion, but it is not commonly applied, or it is applied in regions that may be too different from Europe (e.g. tropical regions) to guarantee that the results will be transposable.
- **Low**: data are not published in reliable information sources and methods are not commonly practiced or are based soley on opinion; This is for example the case of a novel situation where there is little evidence on which to base an assessment.

3. Citations and bibliography. The APA formatting style for citing references in the text and in the bibliography is used.
e.g. Peer review papers will be written as follows:
In text citation: (Author & Author, Year)
In bibliography: Author, A. A., & Author, B. B. (Publication Year). Article title. *Periodical Title*, Volume(Issue), pp.-pp.
(see http://www.waikato.ac.nz/library/study/referencing/styles/apa)