UNIVERSITY OF COPENHAGEN

Københavns Universitet

The giant hogweed best practice manual

guidelines for the management and control of invasive weeds in Europe

Booy, Olaf; Cock, Matthew; Eckstein, Lutz; Hansen, Steen Ole; Hattendorf, Jan; Hüls, Jörg; Jahodová, Sárka; Krinke, Lucás; Marovoková, Lanka; Müllerová, Jana; Nentwig, Wolfgang; Nielsen, Charlotte; Otte, Annette; Pergl, Jan; Perglová, Irena; Priekule, Ilze; Pusek, Petr; Ravn, Hans Peter; Thiele, Jan; Trybush, Sviatlana; Wittenberg, Rüdiger

Publication date:
2005

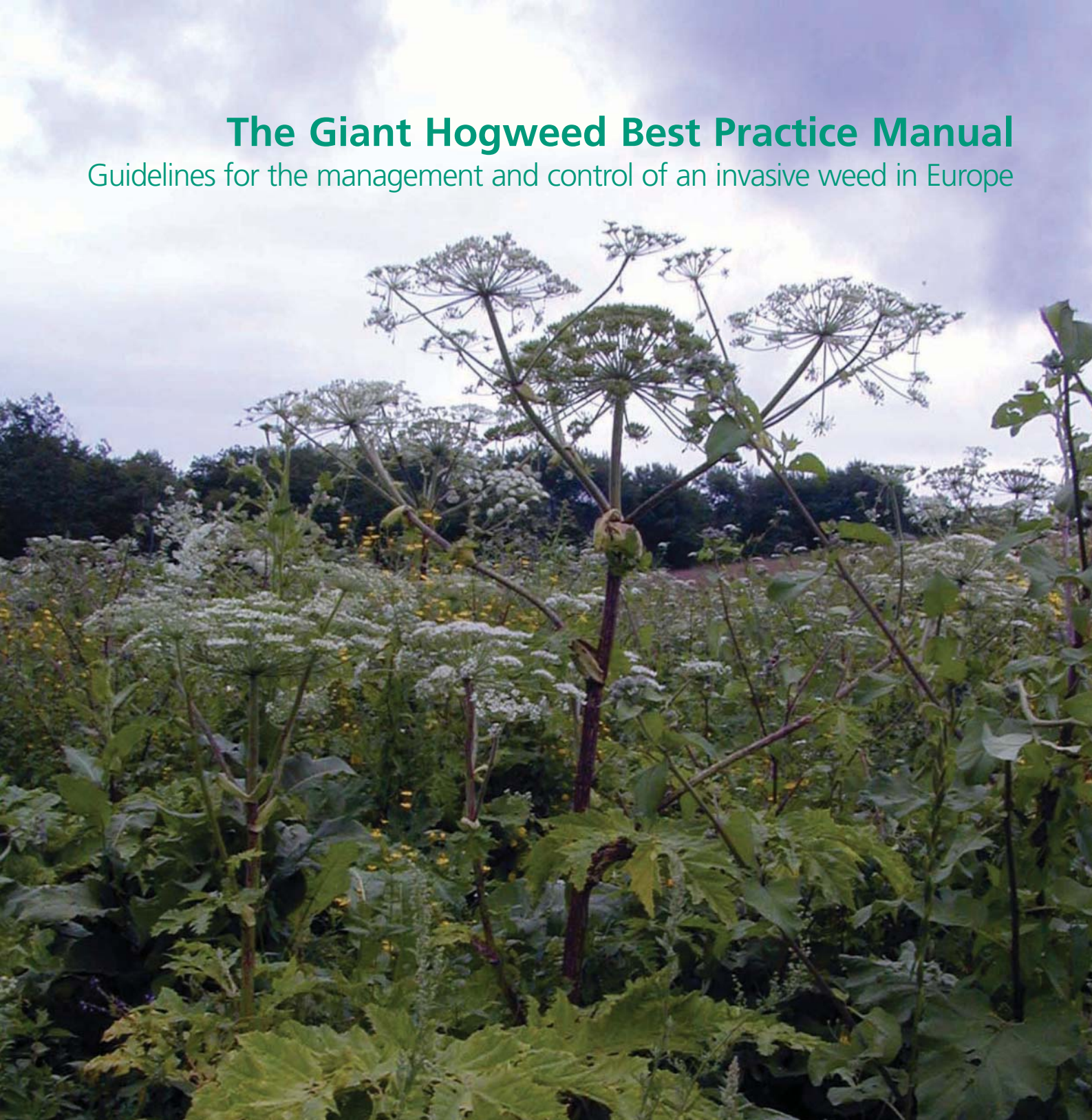
Document version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Booy, O., Cock, M., Eckstein, L., Hansen, S. O., Hattendorf, J., Hüls, J., Jahodová, S., Krinke, L., Marovoková, L., Müllerová, J., Nentwig, W., Nielsen, C., Otte, A., Pergl, J., Perglová, I., Priekule, I., Pusek, P., Ravn, H. P., Thiele, J., ... Wittenberg, R. (2005). *The giant hogweed best practice manual: guidelines for the management and control of invasive weeds in Europe*. Center for Skov, Landskab og Planlægning/Københavns Universitet.

Download date: 13. Nov. 2026

The Giant Hogweed Best Practice Manual

Guidelines for the management and control of an invasive weed in Europe



About the publication

Editors:
Charlotte Nielsen, Hans Peter Ravn, Wolfgang Nentwig and Max Wade

The project:
Giant Alien Project (2002-2005) has been financed by the European Commission within the 5th Framework Programme, 'EESD – Energy, Environment and Sustainable Development', contract no. EVK2-CT-2001-00128.

Project partners are: Danish Centre for Forest, Landscape and Planning, KVL, Denmark; University of Bern, Zoological Institute, Switzerland; CABI Bioscience Switzerland Centre, Switzerland; University of Hertfordshire, Dept. of Environmental Sciences, UK; Justus-Liebig University of Giessen, Institute of Landscape Ecology and Landscape Planning, Germany; Academy of Sciences of the Czech Republic, Institute of Botany, Průhonice, Czech Republic; UFZ – Centre for Environmental Research Leipzig, Department of Ecological Modelling, Germany; Latvian Plant Protection Research Centre, Latvia. The Russian Academy of Sciences, St. Petersburg; Laboratory of Botany, University of Latvia and Gauja National Park, Latvia are sub-contractors of the project.

Publisher:
Forest & Landscape Denmark, Hørsholm Kongevej 11, DK-2970 Hørsholm, Denmark, sl@kvl.dk

Printing:
Gruner Druck GmbH, Erlangen, Germany. Number of printed copies: 2000

ISBN:
87-7903-209-5

Layout:
Inger Grønkjær Ulrich

Citation:
Nielsen, C., H.P. Ravn, W. Nentwig and M. Wade (eds.), 2005. The Giant Hogweed Best Practice Manual. Guidelines for the management and control of an invasive weed in Europe. *Forest & Landscape Denmark*, Hoersholm, 44 pp.

Acknowledgements:
The authours would like to thank the following persons for their contributions to this manual:
Lars Fröberg, Botanical Museum, Lund University, Sweden; Dmitry Geltman, the Russian Academy of Sciences, St. Petersburg, Russia; Zigmantas Gudžinskas, Institute of Botany, Vilnius, Lithuania; Anders Often, Norwegian Institute for Nature Research, Norway.

This brochure is also available in eight languages at the project homepage www.giant-alien.dk

Guidelines for the management and control of an invasive weed in Europe

Authors:

Olaf Booy, Dept. of Environmental Sciences, University of Hertfordshire, UK

Matthew Cock, CABI Bioscience Switzerland Centre, Switzerland

Lutz Eckstein, Landscape Ecology and Landscape Planning, Justus-Liebig University of Giessen, Germany

Steen Ole Hansen, Zoological Institute, University of Bern, Switzerland

Jan Hattendorf, Zoological Institute, University of Bern, Switzerland

Jörg Hüls, Landscape Ecology and Landscape Planning, Justus-Liebig University of Giessen, Germany

Šárka Jahodová, Dept. of Environmental Sciences, University of Hertfordshire, UK

Lukáš Krinke, Regional Museum Kladno, Czech Republic

Lenka Moravcová, Institute of Botany, Academy of Sciences of the Czech Republic, Průhonice, Czech Republic

Jana Müllerová, Institute of Botany, Academy of Sciences of the Czech Republic, Průhonice, Czech Republic

Wolfgang Nentwig, Zoological Institute, University of Bern, Switzerland

Charlotte Nielsen, Danish Centre for Forest, Landscape and Planning, Denmark

Annette Otte, Landscape Ecology and Landscape Planning, Justus-Liebig University of Giessen, Germany

Jan Pergl, Institute of Botany, Academy of Sciences of the Czech Republic, Průhonice, Czech Republic

Irena Perglová, Institute of Botany, Academy of Sciences of the Czech Republic, Průhonice, Czech Republic

Ilze Priekule, Latvian Plant Protection Research Centre, Latvia

Petr Pyšek, Institute of Botany, Academy of Sciences of the Czech Republic, Průhonice, Czech Republic

Hans Peter Ravn, Danish Centre for Forest, Landscape and Planning, Denmark

Jan Thiele, Landscape Ecology and Landscape Planning, Justus-Liebig University of Giessen, Germany

Sviatlana Trybush, Plant and Invertebrate Ecology Division, Rothamsted Research, UK

Rüdiger Wittenberg, CABI Bioscience Switzerland Centre, Switzerland

Contents

Photo: R. Wittenberg

1	Introduction	5
2	Place of origin and historical background	6
3	Identification	10
4	Biology and ecology of the plant	14
5	Seed dispersal	18
6	Effects on surrounding flora	20
7	Public health hazards and safety instructions	22
8	Preventive measures, early detection and eradication	24
9	Evaluation of control methods	30
10	Revegetation	38
11	Planning a management programme	41
12	Literature	42

1 Introduction

Invasive alien plants such as Giant Hogweed give increasing cause for concern. Following on from the problems caused by such invasive weeds in most other continents, Europe too is now beset by alien species that are having severe negative impacts on a variety of ecosystems. Giant Hogweed and other invasive alien plants are leading to a reduction in local plant biodiversity. Additionally, they can cause considerable economic damage, sometimes also presenting a health hazard to humans. No universal tool exists to stop these invasive plants, reduce their impact or prevent future invasions.

Sustainable solutions have to be developed to stop the spread of an invasive species such as Giant Hogweed and the Giant Alien project under the 5th Framework Programme of the European Union has taken an integrated approach to develop just such a sustainable strategy for invasive alien weed management in Europe. The project started in January 2002 and finished in April 2005. It involved eight partners and three subcontractors, and more than 40 scientists from seven countries.

We have studied as many relevant aspects as possible of the biology and ecology of Giant Hogweed in Europe, the invaded area, and in the Caucasus, its native area: Taxonomy and genetics, development and phenology (seasonal changes and growth cycle), population dynamics, pathology, herbivorous insects and their impact on the plants, as well as interactions with soil, nutrients, vegetation cover and land use changes. We especially investigated the effects of herbicides, grazing, pathogens and herbivores and vegetation management schemes as potential control strategies for tall invasive hogweeds. One overall objective of our project was to provide all European authorities (e.g. municipalities, counties, districts, highway agencies, environment agencies) and private landowners with scientifically based but simple and practical management methods to reduce the abundance and prevent further spread of the invasive hogweeds.

This manual is an attempt to disseminate, in a few words, up to date knowledge about all relevant aspects of the biology, ecology, taxonomy and management of invasive hogweeds. This manual mainly refers to *Heracleum mantegazzianum* but is also usable for the closely related *H. sosnowskyi* and *H. persicum.* All members of the project group have contributed to the manual in one way or the other. It is our hope that this manual should encourage European authorities at all levels and private landowners to deal not only with the acute problem of hogweeds but of invasive alien weeds in general. The manual seeks to prevent Giant Hogweed and other species from displacing native plant and animal species, thereby conserving biodiversity across Europe.

More information and downloads of this brochure in several languages are provided on the project homepage: http://www.giant-alien.dk

2 Place of origin and historical background

Giant Hogweed in the native area of western Caucasus

Photo: A. Otte

Over 20 species of the genus *Heracleum* have been variously recorded in Europe. Of these *Heracleum mantegazzianum* Somm. et Levier, *Heracleum sosnowskyi* Manden and *Heracleum persicum* Desf. are considered to make up the group of plants known as Giant Hogweeds. Their height and the large leaf size explain why they are termed the 'giants'.

Heracleum mantegazzianum originates from the western Caucasus, *Heracleum sosnowskyi* is found in the central and eastern Caucasus and western, central, eastern, south-west Transcaucasia as well as north-east Turkey, while *Heracleum persicum* originates from Turkey, Iran and Iraq.

Heracleum mantegazzianum

Heracleum mantegazzianum, the most widespread tall invasive hogweed species, was first described in 1895. However, according to botanical records from several European sources (including the United Kingdom, Norway and the Netherlands), the history of this plant's introduction into Europe had begun much earlier.

The first record of introduction derives from Great Britain in 1817, when *Heracleum mantegazzianum* was recorded on the seed list at Kew Botanic Gardens, London. In 1828, the first natural population was recorded, growing wild in Cambridgeshire, England. Soon after, the plant began to spread rapidly across Europe. Of the 19 countries for which historical data are available, 14 countries (74%) have first records of the plants presence before 1900, two have first records between 1900 and 1960 and the remaining three countries after 1960.

The main mechanism of introduction into Europe, accounting for first records in most of western and northern Europe, was as an ornamental curiosity. Seeds were gratefully received and planted in botanic gardens and the grounds of important estates. This fashion continued for most of the 19th century. The

practice declined and eventually ceased after warnings about the dangers of the plant appeared in western European literature towards the middle and end of the 1900s.

Heracleum sosnowskyi

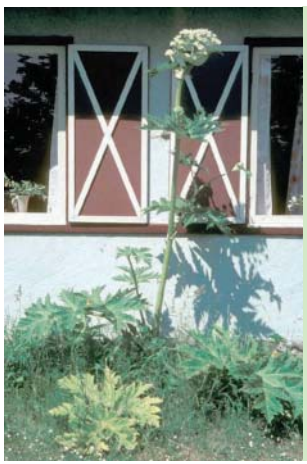
Heracleum sosnowskyi was originally described in 1944 and was introduced as an agricultural crop to Europe where its large biomass was silaged to provide fodder for livestock. Because the plant was hardy and could thrive in a cold climate, it was developed as a crop for north-west Russia, where it was first introduced in 1947. From the 1940s onwards, it was introduced to Latvia, Estonia, Lithuania, Belarus, Ukraine and the former German Democratic Republic. Plantation schemes were eventually abandoned in the Baltic States, partly because the anise scented plants affected the flavour of meat and milk from the animals to which it was fed and also partly because of the health risk to humans and cattle. In parts of northern Russia agricultural production continues to this day.

Heracleum persicum

The taxonomy of *Heracleum persicum* in Europe is less clear, partially because it was the earliest to be described (1829) and some of the subsequent identifications of the plant as *Heracleum persicum* were probably *Heracleum mantegazzianum* or *Heracleum sosnowskyi*. The only known wild populations of the plant in Europe are from Scandinavia, where the Tromsø Palm and *Heracleum 'laciniatum'* appear to be alternative names for this species.

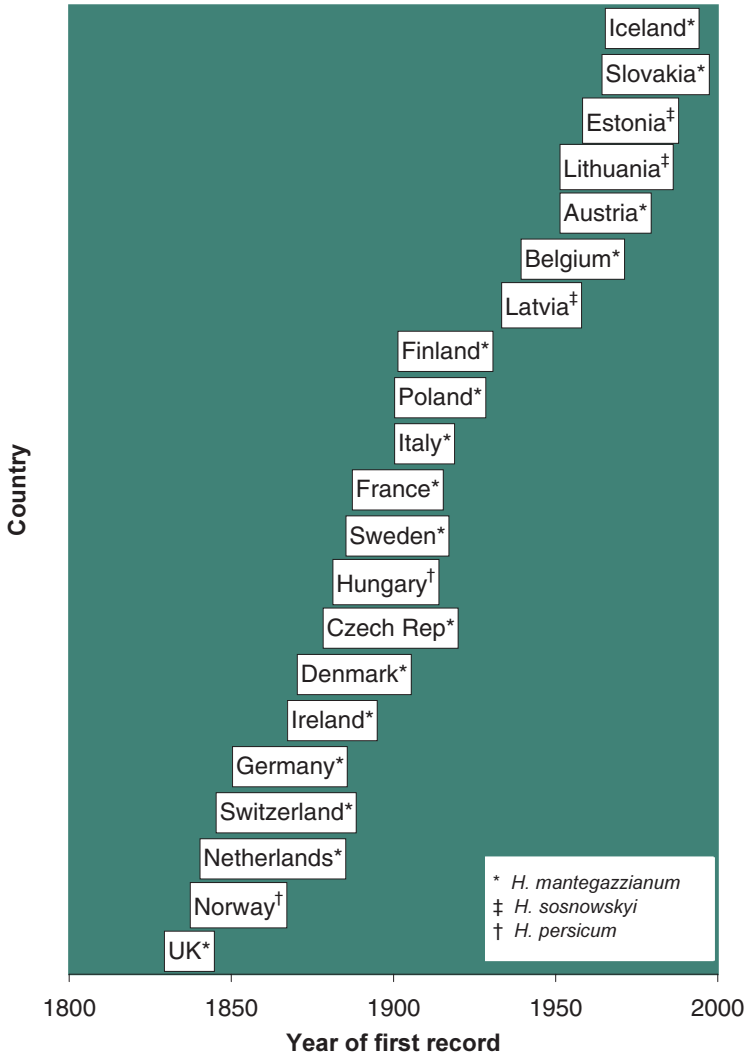
The earliest records for introduction again originate from the seed list at Kew Botanic Gardens in London which show that *Heracleum persicum* was received in 1819. Seeds from London populations of a similar plant were taken by English horticulturalists and planted in northern Norway as early as 1836.

The main mechanism for the spread of this species again appears to be as an ornamental. It is unknown, given the likely introduction of this species into a number of European botanic gardens, why its distribution remains relatively restricted across most of Europe.



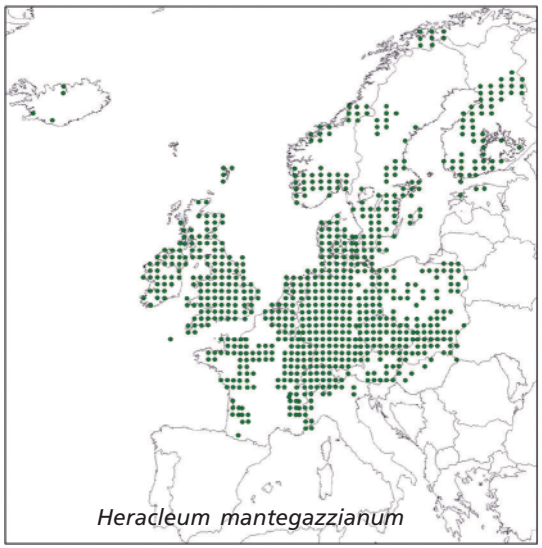
Giant Hogweed was introduced to Europe as a garden ornamental

Photo: H.P. Ravn

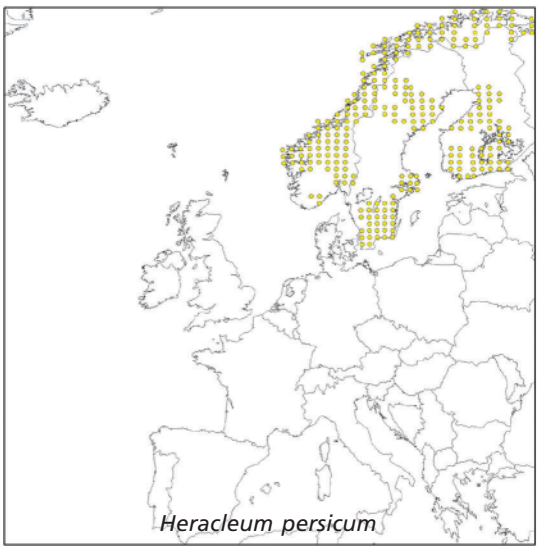


*First records in the wild of tall invasive Heracleum species (*H. mantegazzianum, H. sosnowskyi *and* H. persicum*) throughout Europe*

Current distribution of H. mantegazzianum, H. persicum *and* H. sosnowskyi *in Europe. Distribution data for Norway and France is based on presence or absence at county/department level. As a result the illustrated distribution in these areas may over-represent the actual distribution.* Heracleum sosnowskyi *has also been reported from Belarus, Poland, Russia and Ukraine, however, distribution data could not be located.*



Heracleum mantegazzianum



Heracleum persicum

Heracleum sosnowskyi

3 Identification

Heracleum mantegazzianum

Photo: Donna Ellis, Uni. of Connecticut, www.forestryimages.org

Heracleum sosnowskyi

Photo: O. Treikale

Heracleum persicum
(photo taken in late sommer)

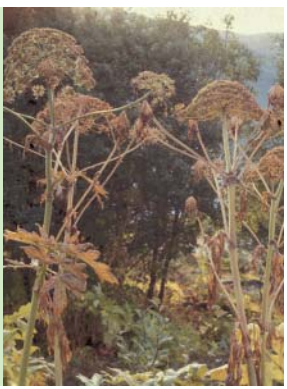


Photo: A. Often

Giant Hogweed is a common name for a group of closely related tall species of the genus *Heracleum* that have been introduced to Europe. They are among the largest herbs in Europe and with their impressive appearance and dominant colonies, the plants are familiar to river authorities and land managers in most central and northern European countries.

Tall invasive hogweeds in Europe – *Heracleum mantegazzianum, H. sosnowskyi, H. persicum*

The most distinct characteristic of these species is undoubtedly their size. They grow up to 4-5 m tall. Stems are usually 5-10 cm in diameter (less in case of *H. persicum*) and are often purple spotted or continuously purple. Leaves of mature plants are divided to a varying extent either into three approximately equal parts which may themselves be similarly divided (ternate) or divided into more than three leaflets arranged in rows along the central leaf stalk (pinnate). Leaves can grow up to 3 m in length. White or rarely pinkish flowers are clustered in an umbrella-shaped head (umbel) that is up to 80 cm across. Each compound umbel has 30-150 rays. A total of more than 80,000 flowers can occur on a single plant. Flowering typically lasts from June to August. The green oval (elliptic) fruits form by July then turn dry and brown with swollen brown oil canals. *H. mantegazzianum* and *H.sosnowskyi* are monocarpic plants (i.e. they die after flowering) while *H. persicum* bears fruit season after season. All tall invasive hogweeds contain phototoxic sap.

Key characters for each species are summarized in the facing table[1].

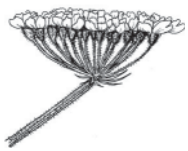
In order to avoid destroying native species that can look similar to tall invasive hogweeds, it is important to be able to distinguish between them. Even experienced managers sometimes have doubt when early in the year the plants are in their vegetative stage and leaves have not grown to their fullest extent. Certain species, mainly of the Apiaceae family, are occasionally mistaken for Giant Hogweed or other tall hogweeds but the former are not usually invasive and, therefore should not be controlled.

Native hogweeds – *Heracleum sphondylium, H. sibiricum*

These plants are close relatives of the tall invasive hogweeds, but are much smaller - usually 60-200 cm in height. The leaves are broad, coarsely divided and very hairy and are usually only up to 60 cm long. White or greenish-yellow flowers are clustered in umbels that are around 20 cm in diameter. The non-invasive hogweeds are common in grassy places, hedgerows and roadsides across Europe (see Table 2).

[1] Taxonomy of tall invasive hogweeds is not fully clarified, and the descriptions of *H. mantegazzianum*, *H. sosnowskyi* and *H. persicum* are preliminary.

Table 1. Features of tall invasive hogweed species

Plant species	Height (cm)	Stem	Leaf	Flower	Fruit	Distribution
Giant Hogweed *Heracleum mantegazzianum*	200-400 (-500)	Shaggy (villous) upper stem; lower stem coarsely ridged and more or less hairy. Stem up to 10 cm thick at base with purple blotches				Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Hungary, Iceland, Ireland, Italy, Liechtenstein, Luxemburg, Netherlands, Norway, Poland, Russia, Slovakia, Sweden, Switzerland, UK incl. Northern Ireland Possible occurrence in: Belarus, Estonia, Latvia, Lithuania, Ukraine
Heracleum sosnowskyi	100-300	Ridged, sparsely hairy stem with purple blotches very similar to Giant Hogweed		White flowers. Outer petals radiate, 9-10 mm long. Slightly convex compound umbels, 30-50 cm across. 30-75 rays with only short hairs		Belarus, Estonia, Germany, Hungary, Latvia, Lithuania, Poland, Russia, Ukraine
Heracleum persicum	(-100) 150-300	Stem purple, 1.5-2 cm thick at the base. Whole plant has anise odour				Denmark, Finland, Norway, Sweden, Possible occurrence in: Hungary, Latvia, UK

Drawings; J.C. Schou

Photo: O. Treikale

Leaves of *Heracleum sosnowskyi (left) and H. mantegazzianum (right)*

Photo: C. Nissen

Table 2. Features of native hogweed species

Plant species	Height (cm)	Stem	Leaf	Flower	Fruit	Distribution
Cow Parsnip/ Hogweed *Heracleum sphondylium*	80-200 (-300)	Lower stem sparsely hairy, upper stem more densely hairy. Deeply ridged				Most of Europe except the extreme north and much of the Mediterranean region
Heracleum sibiricum	60-100	Lower stem densely hairy, upper stem slightly hairy. Ridged stem	Simply pinnately divided with lobed 5-7 segments, margin with low, rounded or scalloped projections or saw-like margin. Rather densely hairy beneath	Flowers greenish-yellow. Outer petals not or only slightly radiate. Rays of umbels with scattered small hairs, almost smooth. 12-25 rays	Fruit egg-shaped; 7-8 mm long, 5-6 mm wide. Smooth	North-eastern and central-eastern Europe as well as central and south-west France

Drawings: J.C. Schou

Heracleum sphondylium

Photo: Biopix.dk

Heracleum sibiricum

Photo: Biopix.dk

Other species that can be mistaken for tall invasive hogweeds

Wild Parsnip (*Pastinaca sativa*) is easily distinguished by its yellow flowers and leaves that are simply divided into more than three leaflets arranged in rows along the central leaf stalk (pinnate) with v-shaped base. The plant is common on roadsides and in grassy places and is distributed in most of Europe except the Arctic, but only as an escape from cultivation in parts of the north. Sap can also cause photodermatitis.

Wild Parsnip (*Pastinaca sativa*)

Photo: Biopix.dk

Garden Angelica (*Angelica archangelica*) is a common garden plant that is cultivated for its aromatic stems and oils distilled from the seeds and root. The plant grows 100-230 cm tall, umbels are strongly convex with greenish flowers and the egg-shaped fruits are without conspicuous oil ducts. It has become naturalized on river-banks and in waste places in north and east Europe. The sap can cause damage to the skin.

Garden Angelica (*Angelica archangelica*)

Photo: Biopix.dk

Wild Angelica (*Angelica sylvestris*) somewhat resembles Garden Angelica and both species might be confused with Giant Hogweed due to their remarkable height (up to 200 cm or more), purplish stems and large inflorescence. Wild Angelica is almost hairless and has characteristic purple bands at the base of leaf and leaflets. It is common across Europe and grows in damp places, and in particular beside lakes and streams.

Wild Angelica (*Angelica sylvestris*)

Photo: Biopix.dk

4 Biology and ecology of the plant

Flowers are arranged in umbels

Photo: C. Nielsen

Flowering and seed production

Giant Hogweed plants can live for several years but die after bearing seeds once. They persist in a rosette stage and usually flower in the third to fifth year. Under unfavourable conditions such as on nutrient poor, shaded or dry sites or when regularly grazed, flowering is postponed until sufficient reserves have been accumulated. Given such conditions, plants can live for at least 12 years. On average, it flowers in Europe earlier than in its native Caucasian range. They do not reproduce vegetatively and rely exclusively on reproduction by seed. Understanding the plant's flowering biology and mechanisms of reproduction is crucial for successful control and/or eradication.

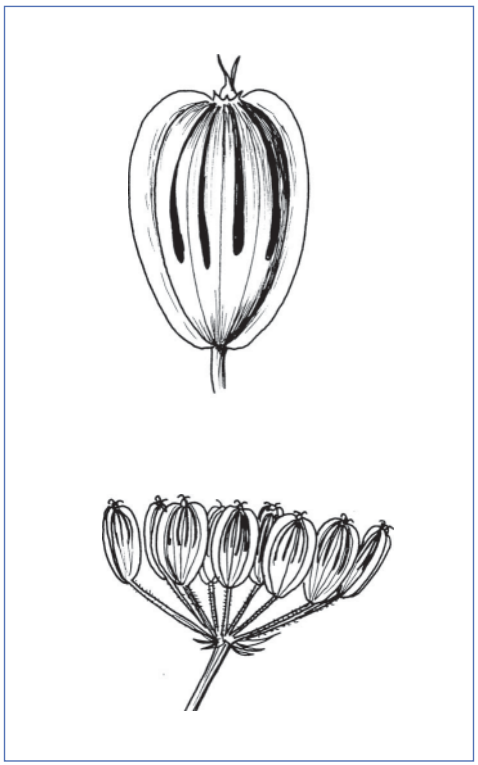
Flowers are arranged in compound umbels and are composed of insect-pollinated, hermaphrodite flowers (having both male and female parts in the same flower) where pollen grains mature before the female reproductive structure becomes receptive. Seeds normally result from fertilisation between two plants (outcrossing), but there is an overlap in male and female phases, which makes self-fertilization possible. Seeds produced by self-pollination are viable; more than half of them germinate and give rise to healthy seedlings. This means that even a single isolated plant, resulting from a long distance dispersal event, is capable of founding a new population.

In central Europe, plants flower from mid June to late July and seeds are released from late August to October. What is technically known as the fruit consists of two winged mericarps, each containing one seed. For simplicity, the unit of generative reproduction is termed 'seed' in this manual, instead of the correct technical term 'mericarp'. An average plant bears about 20,000 seeds (almost half of them on the terminal umbel), but individual plants with over 100,000 seeds have been reported. Although some of the seeds are dead and never germinate, the reproductive potential of the plant is enormous.

Seed bank and germination

After release from the umbel, seeds mature in a short-term persistent seed bank which is an important mechanism of population development. The majority of seeds (95%) are concentrated in the upper 5 cm soil layer. In autumn, the seed bank in dense stands contains up to 12,000 living seeds/m^2 (on average 6,700 were recorded). Some seeds in the seed bank are dead, some decay during winter, yet there are on average more than 2,000 living seeds/m^2 in spring, vast majority of which are ready to germinate because they have lost dormancy over winter.

Dormancy is defined as a state in which the seed does not germinate although external conditions are suitable. Seeds of many plant species can remain buried in the soil for long periods of time with little damage, provided the conditions are favourable and these seeds are known as the seed bank. This allows the seeds to wait for favourable conditions and reduces the mortality of newly emerging seedlings. When released from the umbel, seeds of Giant Hogweed contain an underdeveloped embryo and almost all seeds are dormant and do not germinate in autumn. Before germination, a period of embryo growth and breaking of dormancy by cold and wet conditions is required. A period of two months at 2-4°C is sufficient to break dormancy under experimental conditions; in the field, dormancy is broken during autumn and winter.



Left:
The fruit consists of two winged mericarps, each containing one seed.

Drawings: J.C. Schou

Right:
Almost all the seeds produced in late summer are dormant and do not germinate in autumn. Dormancy is broken by cold and wet conditions during autumn and winter

Photo. H.P. Ravn

Drawing: J. Ochsmann.

Seedling and leaf development of Giant Hogweed.

During spring germination, the short-term persistent seed bank is largely depleted due to germination and in summer it only contains about 200 living seeds/m^2. These remain dormant and about 8% are found to survive in the soil for more than one year; about 5% survive for two years after release from the parent plant. Published information on how long seeds survive in the soil seed bank varies and is to a large extent unreliable as it was only inferred from indirect evidence. This can be reliably assessed only experimentally, by burying seeds and following their fate over time. Nevertheless, the fact that at least a small fraction of seeds survive for at least two years is crucial for the course of invasion and application of adequate control measures. Given the high fecundity (capacity to produce offspring), a single plant germinating from a seed bank could start a new invasion.

After dormancy is broken, seeds germinate very easily (about 90% of the total seeds produced the previous year germinate under laboratory conditions at 8–10°C). In the field, seedlings reach high densities up to several thousands/m^2 early in spring (March to April). Although 98% of seedlings die in competition with their siblings during the process of self-thinning and due to shading by adult plants, the surviving plants in the following years create populations with almost complete cover of large leaf rosettes. Rapidly developing populations shade out other species and Giant Hogweed can attain dominance in invaded sites. On average about 10% of plants flower and complete their life cycle, while the remainder survive in the rosette stage to the next year.

Biological and ecological characteristics of invasiveness

The main biological and ecological characteristics of Giant Hogweed that make it such successful invader can be summarized as follows:

- germination in early spring before the resident vegetation appears;
- low mortality of plants once they become established;
- fast growth of rosettes allowing rapid development of populations and the ability to form dense cover and place leaves above the resident vegetation;
- stable proportion of plants that flower and produce seeds;
- ability of plants under stressful conditions to postpone flowering until a time when sufficient reserves are stored;
- flowering sufficiently early in the vegetation period, which makes it possible to complete the development of seeds;
- ability of self-pollination leading to production of viable seed;
- high fecundity allowing a single plant to start an invasion;
- high density of seeds in the soil seed bank, with some seeds surviving for at least two years;
- efficient breaking of dormancy by cold temperatures during winter;
- extremely high percentage of germination regardless of where on the mother plant the seeds are produced;

These features, together with efficient seed dispersal by human activities, water and wind, give Giant Hogweed enormous invasion potential. Most of them apply to other invasive hogweeds, too.

High density of seedlings, Russian Caucasus

Photo: M.J.W. Cock

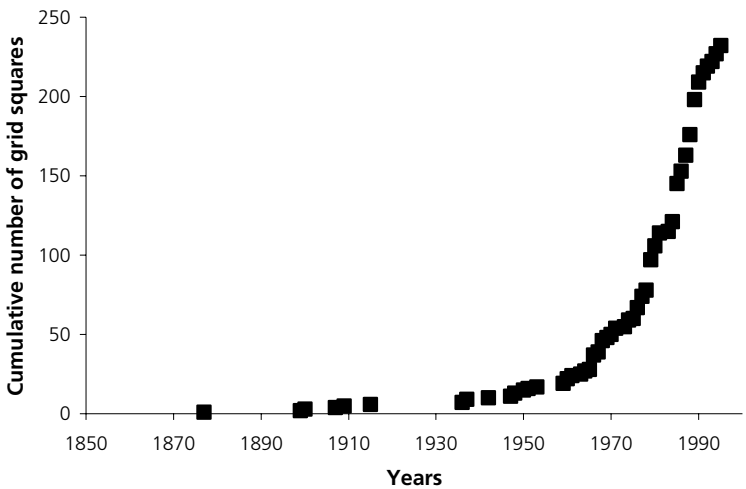
5 Seed dispersal

Photo: P. Pyšek

What is the fate of the enormous number of seeds produced by Giant Hogweed?

The majority of seeds are released into a short-term persistent seed bank in close vicinity of the parent plants. In individuals of about 2 m tall, 60-90% of seeds fall on the ground within a radius of 4 m of the parent plant and the density of seeds declines rapidly with increasing distance from the seed source. Some seeds are spread into more distant surroundings and may contribute to invasion of new sites.

Invasion dynamics of Giant Hogweed in the Czech Republic (grid sections are 11 by 12 km)



Seeds may spread over long distances, but the majority of seeds are shed close to parent plants

Photo: P. Pyšek

Several main modes of seed dispersal are known in Giant Hogweed, some are natural and some are human assisted. Populations often grow along streams and rivers and the water can spread seeds very efficiently, in large numbers and over considerable distances. Long distance dispersal events that transport the seeds far from the source population are important mechanisms of plant dispersal, e.g. during extreme events such as floods.

Giant Hogweed is also spread by various human activities; e.g. road ditches and margins are among this species most typical habitats. Seeds stick to tyres of passing cars and can be spread far from the place where they were produced. Whole umbels with dry seeds are sometimes transported by people as they are decorative. In addition, various mechanisms of seed dispersal by human activities are involved, such as translocation of seeds with soil or dispersal of seeds attached to clothes or animal fur, e.g. sheep and cattle. Wind is an important vector of local dispersal, especially in winter when seeds are blown over the frozen or snow-covered soil surface.

If suitable sites are available, a high rate of spread is possible at both local and regional scales. At the local scale, an invading front of Giant Hogweed populations has been observed advancing in the Czech Republic at an average rate of about 10 m/yr, and the area invaded increased by more than 1,200 m^2 each year in a heavily invaded region. At the country scale, the number of localities doubled each 14 years during the phase of rapid invasion. These values compare favourably with other prominent invasive alien species worldwide.

6 Effects on surrounding flora

Open stand of Giant Hogweed

Photo: J. Hüls

Tall invasive species of hogweed can create stands of different forms and densities. These stands may range in extent from square metres to hectares, and small patches, linear stands or fringes can be found, e.g. along a river. Such narrow stands may nevertheless be conspicuous owing to the species' large stature, but they hardly occupy much ground area. The density of populations of Giant Hogweed may also vary considerably. In large areas of the plant, density may range from sparse growth (1-3 adult individuals/10 m^2) to dominant stands in which Giant Hogweed occupies almost the whole ground area (more than 20 adult individuals/10 m^2).

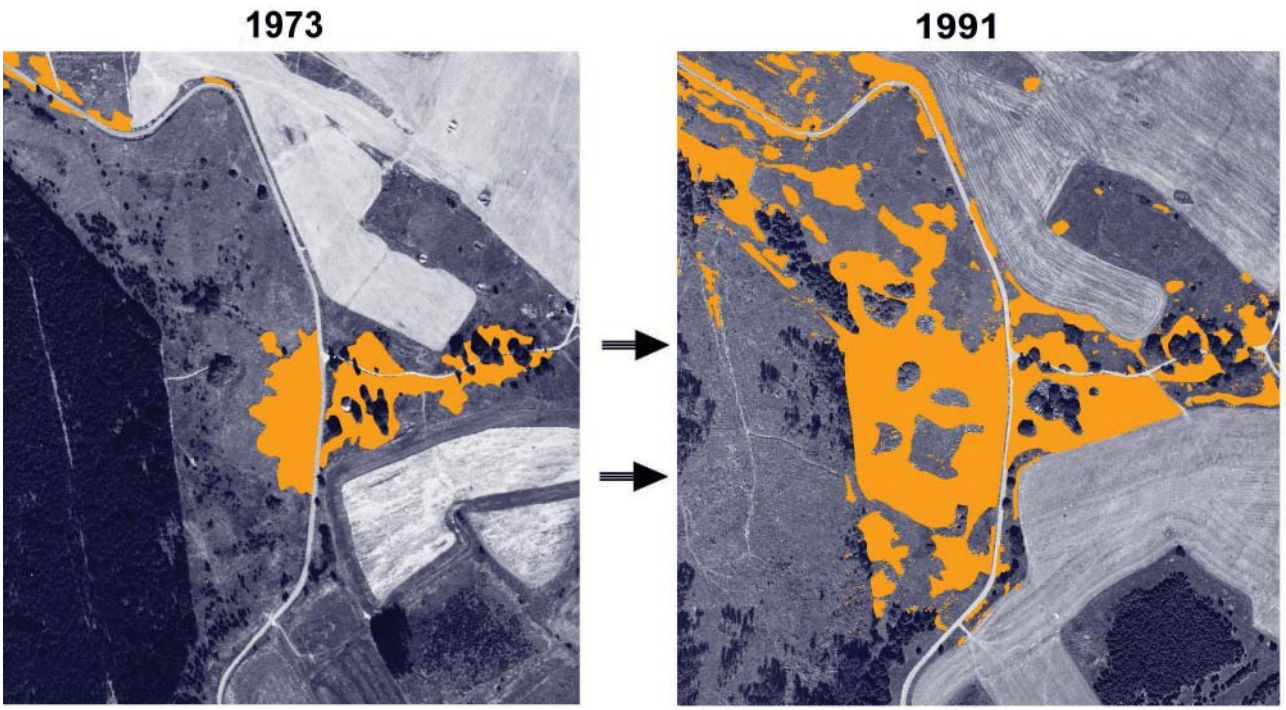
Dense stand of Giant Hogweed

Photo: J. Hattendorf

The enormous height and leaf area of tall invasive species of hogweed, extraordinary for a herbaceous species, enable plants to overtop most indigenous plant species and hence, it is a strong competitor for light. In dominant stands up to 80% of the incoming light is absorbed by it, such that other light demanding species will be suppressed.

Giant Hogweed may change the composition and species diversity of indigenous plant communities and in central Europe investigations have shown lower species richness and densities in areas occupied by Giant Hogweed than in non-invaded areas. Additionally, stands of high density of Giant Hogweed contain fewer species than stands with lower Giant Hogweed densities.

Giant Hogweed will reach high densities in abandoned grasslands and ruderal habitats, leading to a strong decline in the species richness of these habitats. However, loss of species diversity as a consequence of abandonment and ruderalisation and the development of species-poor dominant stands is not a phenomenon exclusive to Giant Hogweed. Under certain conditions loss of species diversity can also be caused by indigenous species (e.g. Stinging Nettle, *Urtica dioica*). Giant Hogweed should not be considered as the only threat, but rather as a part of a process affecting habitats and landscapes, which may lead to reduced local species richness.



On-going invasion (orange areas) of Giant Hogweed in the Czech Republic

Aerial photography created by Military Geographical and Hydrometerological Office, Dobruška, Czech Republic

7 Public health hazards and safety instructions

Photo: J. Hattendorf

Besides the ecological problems, tall invasive hogweed species also represent a serious health hazard for humans. The plant exudes a clear watery sap, which contains several photosensitizing furanocoumarins (synonym for furocoumarins). In contact with the human skin and in combination with ultraviolet radiation, these compounds cause burnings of the skin. The content of furanocoumarins varies among plant parts, however, during the season skin contact should be avoided at any time even in the absence of sunlight (specifically ultraviolet radiation). The phototoxic reaction can be activated by ultraviolet radiation only 15 minutes after contact, with a sensitivity peak between 30 min and two hours. In addition, several furanocoumarins have been reported to be carcinogenic (i.e. they cause cancer) and teratogenic (i.e. they cause malformations in the growing embryo).

After a period of about 24 hours flushing or reddening of the skin (erythema) and excessive accumulation of fluid in the skin (edema) appear, followed by an inflammatory reaction after three days. The reaction of the skin will also depend on individuals' sensitivity. Approximately one week later a hyperpigmentation (unusual darkening of the skin) occurs on the affected areas, which can last for months. The affected skin may remain sensitive to ultraviolet light for years. Moisture, e.g. sweating or dew, and heat enhance the skin reaction.

The main groups at risk are people coming into contact with the plant through their work such as gardeners or landscape workers. Weeding without gloves and the use of power tools without adequate protection frequently lead to phytophotodermatitis. Children are at particular risk, e.g. using the hollow stems as pea shooters or spyglasses. Due to the fact that contact with the plant itself is completely painless, workers and children in contact with the plant can continue with their action often for hours.

Safety instructions

Everyone operating in areas infested with tall invasive hogweed species should be made aware of the health risks associated with this plant. It is necessary to avoid touching or stroking the plant with the bare skin, and to prevent ultraviolet light from reaching exposed skin. Toxicity may result from any activity that involves bruising, cutting or touching the foliage. All body parts must be covered with protective clothing. Synthetic water-resistant materials are preferred, since cotton and linen fibres soak up the plant sap and can be penetrated by plant hairs. Gloves with long sleeves should be worn and, if cutting this plant, protective goggles or glasses must be used to prevent drops of plant sap entering the eyes. Care should be taken not to scratch or otherwise touch exposed skin with gloves covered in sap. Modern power equipment such as trimmers or weed whackers can spray pulverized plant material; therefore, it is essential to wear additional safety goggles or glasses and protection from inhalation.

In case of exposure to plant sap, one should wash the skin carefully with soap and water as soon as possible and subsequently keep the area away from sunlight for at least 48 hours. Treatment with topical steroids early in the reaction can reduce the severity and ease discomfort. In the following months, a sun-cream should be used for the sensitive areas. If sap goes into the eyes, rinse them with water and use sunglasses. Do not hesitate to seek medical advice, particularly after intensive contact.

Photo: J. Pysková

Photo: USDA APHIS PPQ Archives, www.forestryimages.org

8 Preventive measures, early detection and eradication

How to minimise invasion of new areas

In order to efficiently prevent the spread of tall invasive species of hogweed and to optimize use of financial resources, preventive measures should be targeted at those areas most likely to be reached by seeds of invasive hogweeds that also present suitable habitats. There are several components to this prevention, early detection and rapid response approach:

- establishment of policies and guidelines for best practice;
- identification of routes of entry of seeds and areas likely to be reached by seeds;
- identification of habitats most vulnerable to invasion;
- an awareness raising programme;
- surveys and other mechanisms to monitor the spread of invasive hogweeds and especially to locate newly established populations;
- an eradication campaign, where preventative measures fail, and
- follow-up monitoring.

The first stage, therefore, is to map the distribution of all extant populations especially in adjacent invaded regions. Owing to their large size, stands of tall invasive hogweeds are very conspicuous for most of the year, both alive and dead, and especially during flowering in early summer. It is therefore relatively easy to determine the plant's distribution. This combination of characteristics also makes it particularly suitable for involving the public in locating stands through a public awareness raising campaign. The general public can be informed of the problems caused by the invader and asked to help identify populations and even single plants of invasive hogweeds. This can be done using internet sites for a particular area, local papers, radio and television programmes and posters, brochures and leaflets. A focussed programme of awareness raising needs to be developed. Awareness raising should be targeted at key groups, e.g. road and river managers and companies deliberately or inadvertently transporting soil. Groups involved in outdoor activities, such as fishermen, farmers, hunters, environmental groups, hiking and cycling clubs, can be directly targeted. The public needs to be aware (or easily able to find out) where their observations should be reported. Another useful method, which could be used to determine the distribution of these conspicuous aliens, is aerial photographs during the flowering and early fruiting period (from the second half of June to July).

The relevant body, after receiving information about a possible new infestation, needs to have the resources to immediately visit the site to confirm the identification, assess the situation, including land ownership and access, the extent of the invasion and control options. Table 3 (page 27) provides an example of relevant survey variables to consider. The details of the information to be recorded will depend on the storage system and the intended analysis of data. The storage system can vary from a simple system based on recording sheets or cards and a map made by hand to show the sites, to the employment of computer databases or the use of a Geographical Information System (GIS).

In order to colonise a new area, seeds of invasive hogweeds have to reach it, whether dispersed by natural or human assisted mechanisms (see chapter 5 Seed dispersal). Areas that are more likely to be reached by seeds of hogweed are those parts of a landscape that are:

- within wind dispersal distance of existing stands, but not protected by barriers (e.g. dense scrubland and forest);
- within the flood zone of water courses, where tall invasive species of hogweed occur in the upstream flood area;
- road or railway border within 2 km of another invasive hogweed patch along the border;
- adjacent to gardens in which invasive hogweeds are cultivated.

High risk points of entry should be identified and visited. Regular checks of these areas could be combined with monitoring for other alien problem plants.

It is necessary to know the species' habitat preferences in order to recognise those areas that are both susceptible to colonisation and are most vulnerable to invasion. For example, in central Europe, an analysis of habitats colonised by Giant Hogweed showed that this species preferentially establishes itself on abandoned grassland, in ruderal places and in fringes along watercourses, woodlands and roads, whereas areas under agricultural or horticultural use (e.g. arable crops, pastures and gardens) are unsuitable habitats. However, after infrequent use or abandonment of these unsuitable habitats, Giant Hogweed may invade and develop dominant stands. Habitat quality is also critical for establishment and further spread. In general, habitats suitable for invasion are characterised by high sunlight, no active land use, human changes to the vegetation cover, and good water availability and soil nutrient supply.

Stands of Giant Hogweed (white dots in the circle) in an aerial photograph

Photo: Military Geographical and Hydrometerological Office, Dobruška, Czech Republic

Photo: J. Hattendorf

Where to act?

Using the information gathered from the distribution survey of invasive hogweeds, and knowing the mechanisms by which seed entry can occur, it is possible to determine areas likely to receive seed input. Combining this with information about the habitats in these areas enables the sites most vulnerable to invasion to be determined. Using GIS, it is possible to correlate the distribution of tall invasive species of hogweed and other data, such as land use, habitat quality, proposed developments and planning policy. As data are collected and stored, distribution maps can be used to explore corridor effects, highlight the habitats that tend to be associated with the plant and areas at risk of infestation. Resources available for control of invasive hogweeds might be limited but having a mapped distribution of the plants will enable local authorities to focus on control at key sites and prevent further spread of the plant. Based on field observations and integration of the survey data with other mapped information, a decision about the management of invasive hogweeds in the area can be taken and an implementation plan agreed with those concerned.

What to do?

Preventive counter measures should include the prohibition of seed input and the regulation of habitat quality in areas prone to Giant Hogweed invasion. To reduce seed input into unoccupied areas in the first place, sowing and planting of tall invasive species of hogweed in gardens, parks and the open landscape should be prohibited. Additionally, unintentional transport of seeds, e.g. through transfer of soil material, should be avoided. Extant stands along transport habitats (water courses, highways) should be managed to prevent dispersal of seeds.

In areas prone to invasion that are agricultural land or otherwise managed, management should be continued for as long as possible in a regular fashion, e.g. annually and with sufficient intensity. This is especially important in the case of field margins and fringes along roads, paths, arable crops, meadows and watercourses. Mowing and grazing are suitable for the management of grasslands and grassland-like fringe habitats. Mown plant material should be removed from the area if possible. It should not be piled in heaps on grassland since this will damage the vegetation cover and create favourable conditions for establishment of invasive hogweeds. Abandoned fields should be kept under observation as they can be easily invaded, especially areas with patches of exposed soil. Where an area of land at high risk of invasion has no agricultural interest or regular management, afforestation of the area would serve to prevent invasion, as the shading effect of the trees will inhibit establishment of tall invasive species of hogweed. Both trees and shrubs appear to be suitable for this kind of management. The saplings planted should be of a size to ensure the rapid establishment and development of a closed canopy.

Damage to the original vegetation cover should be avoided in areas prone to invasion. This includes deposition of plant material from gardens and other wastes, soil surface destruction through agricultural machinery, removal of single shrubs and trees in the open landscape and along margins of forests and scrubs and generally all actions that open gaps within a dense vegetation cover.

Table 3. Survey variables relevant for mapping and monitoring stands of tall invasive species of hogweed.

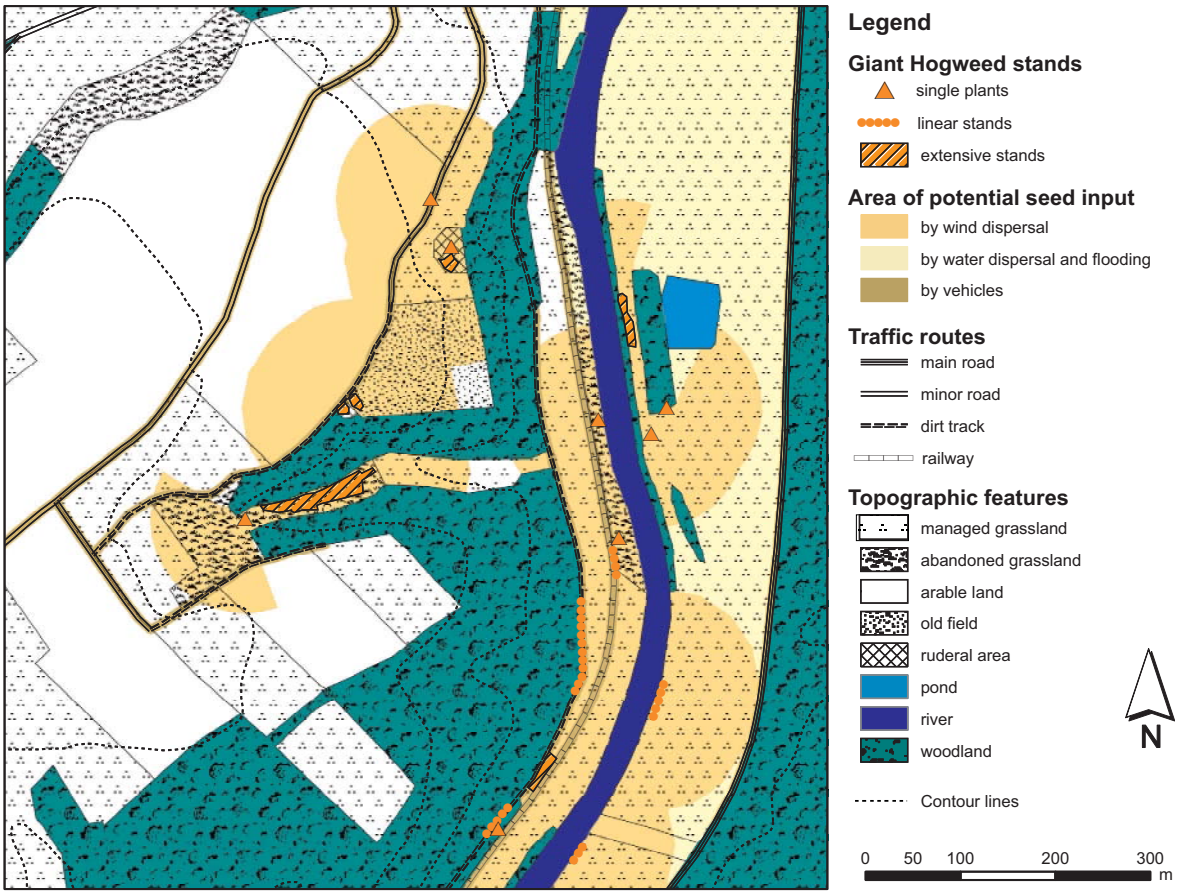
Aim	Parameter	Description
Identification of the stand	Site reference, date of detection and name of recorder	Each site is assigned a serial number as the stands are identified in the field
	Location	Description of the exact location of the plants, map grid reference
	Land ownership	Private, public, owned by funds or the church
	Land register number	Optional
Population description	Stage of the plant	Vegetative, flowering, fruiting, dead
	Area	Area covered by the plant, m^2
	Density	Estimation of the number of plants per m^2
	Number of plants	Area covered by the plant and density of the stand provide the basis for an estimate of the number of plants
	Land use	Agricultural land, river bank, waste ground etc.
	Area access and ground condition	Distance to the nearest paved road and evaluation of ground carrying capacity for heavy machinery
Prediction of biodiversity loss and impact if not controlled	Biological quality of an area	Description of the current plant community, species richness, habitats or species under threat due to invasive aliens etc.
	Recreational value	Evaluated in terms of public access to an area, proximity to houses and the suitability of the area for recreational purposes
	Risk of erosion of soil, especially into streams or rivers	The density of ground vegetation and the degree of slope will affect the risk of erosion – rate as high, medium or low
Management and control	Management history	Status of control, special circumstances to consider
	Control measure	Suggested control method based on an immediate assessment and judgement in the field

If prevention methods fail and invasive hogweeds colonise a new area, early detection of new populations is essential to facilitate a rapid eradication response. While new infestations are still small, eradication efforts are cheaper and more likely to be successful. Therefore, a national or local strategy to manage and contain invasive hogweeds, should include an early detection programme. Early detection, however, will only be useful if the strategy is backed up with a contingency plan for eradication. This plan needs to identify responsible organisations or groups committed to take rapid action, and to ensure that they have appropriate financial, human and material resources. Actions will only be successful, if they are embedded in management plans integrated across different regional and local authorities. If these actions are restricted to the responsibilities of a single authority or officer, spread of invasive hogweeds outside the area of administration may jeopardise management success.

The next step is to eradicate the population using an appropriate method (see chapter 9 Evaluation of control measures). Subsequently, the infestation area, including adjacent areas that might have recei-

Through public awareness raising campaigns using local papers, internet sites, radio and television programmes the general public can be informed of the problems caused by invasive hogweeds, and asked to help locate new infestations.

ved seeds (e.g. downstream from a riverside infestation), should be monitored and any regrowth or new infestations eradicated. Since the seeds can survive for several years in the soil, follow-up monitoring of the eradication site for at least five years must be undertaken both within and outside the area to be protected. Plants in the first year are more difficult to find, so this should be undertaken by staff familiar with the plant in its vegetative stages. Any increases or decreases in the distribution of tall invasive species of hogweed should be recorded in the distribution database.



Landscape scheme of Giant Hogweed stands and buffer zones around stands which could be reached by seeds transported by wind, water, cars, etc.

9 Evaluation of control methods

Regardless of control method, the treatment of plants should be started early in the growing season

Photo: P. Pyšek

Safety instructions

Protective water-resistant clothing and protective glasses or goggles must be worn by the personnel when conducting the recommended cutting techniques due to the risk of skin contact with splashes of the toxic sap and sap coated fragments of the plant (see chapter 7 Public health hazards and safety instructions).

Currently used control methods comprise a variety of manual and mechanical methods, grazing and herbicide application. Rather than recommending a single control method, a control programme based on an Integrated Weed Management Strategy (IWMS) is preferred. An IWMS should focus on optimal management with respect to efficacy, ecology and economy. It necessitates flexibility in the methods that are chosen in order to match the management requirements of each specific location. The selection of control methods depends on the area covered by the plant, plant density and accessibility of the stand. Regardless of the control method, management usually requires repeated and correct application in order to obtain satisfactory control. Accordingly, to make the most of the control efforts, the treatment of plants should be started early in the growing season and continue for several years until the soil seed bank is depleted and the root system has died. The cost of controlling tall invasive hogweeds varies considerably depending on the control method used. Differences in availability of equipment and price of labour will influence 'best choice'. Efficiency, recommendations, and time for control for the different methods are described below and summarized in Table 4.

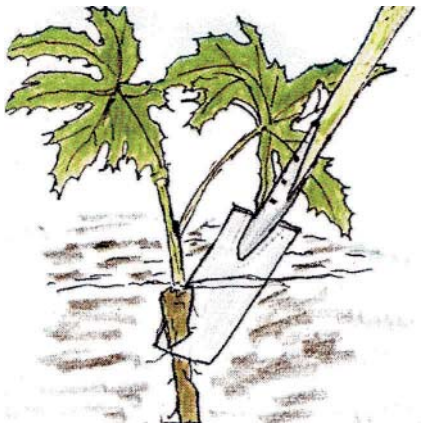
Manual and mechanical control methods

Manual and mechanical control methods include different control techniques such as root cutting, cutting the plant, mowing, and umbel removal. Except for root cutting, mechanical control does not cause the immediate death of the plants. Death occurs after two to three treatments per year during several growing seasons through depletion of nutrient reserves. Ploughing can control an infestation of tall invasive hogweeds on agricultural land. Deep ploughing of the soil (up to 24 cm) will significantly reduce the germination of hogweed seeds due to the upper soil (where the majority of the seeds are concentrated) being buried. The best results are obtained if the established vegetation of invasive hogweed plants is controlled mechanically or chemically prior to the ploughing.

Root cutting (or digging) is usually performed with an ordinary spade with a sharpened blade. The cutting should take place in early spring and be repeated in mid summer. It is recommended that the root is cut at least 10 cm below soil level. However, due to such factors as soil erosion, additional soil layers may cover the plants and such individuals should be cut further down, e.g. up to 25 cm below soil surface. The cut parts of the plants are pulled out of the soil and either destroyed or left to dry out. The method is very effective, but labour intensive and therefore recommended to be used only for single plants and smaller stands (<200 individuals).

Mechanical mowing techniques, for example a flail mower, are useful for large infested areas. The plants will rapidly recover with basal regrowth and mowing must be repeated 2-3 times during the growing season to hinder the re-sprouting plants from storing nutrients in the root and then flowering and setting seeds. If the population is small or situated in a location unsuitable for mechanical mowing, e.g. along rivers or on slopes, the plants can be cut manually by using a scythe or a trimmer. One strategy of cutting is to cut only the flowering plants at mid-flowering stage. Production of new seeds will be prevented and vegetative plants will out-shade each other. When repeated carefully this strategy should with the least efforts eradicate the population in a few years.

Removal of umbels can be as effective as cutting the whole plant, but this control method often fails to prevent seed production due to the high regeneration potential. Plants subjected to removal of flower heads can readily regenerate and produce new flowers and viable seeds of normal size that germinate well. Timing of removal is crucial because if the treatment is applied too early in the season (before full inflorescence), regeneration is very vigorous and an even larger number of seeds is produced. If treatment is too late (at the beginning of seed-setting), there is a risk that seeds will ripen even on cut umbels that are left lying on the ground. The cut umbels must be collected and destroyed. The removal of umbels is most effective if done when terminal umbels just start to flower. Even then, there is some regeneration and treated stands must be checked at the time of seed ripening to prevent release of seeds produced by regeneration. This method should only be considered as an improvised solution for control of stands where no other attempts of control have taken place earlier in the season.



The root must be cut at least 10 cm below soil level. Plants in pastures have deeper roots and they should be cut 10 cm below the top of the root

Drawing: P. Leth, County of Vestsjælland, Denmark

Tall invasive species of hogweeds have a high regeneration potential and cutting treatment must be conducted 2-3 times during the growing season in order to stop plants from setting seed

Photo: C. Nielsen

An innovative practitioner has developed a special tool, 'the Hogweed tool', which consists of a curved saw blade on a long handle that cuts down the stem at a safe distance away from the plant. However, removal of the stem necessitates the same crucial timing for umbel removal due to the regrowth potential of the plant, otherwise the treatment must be repeated later in the season to prevent the seed from maturing.

Grazing

Grazing has proved to be very efficient for the control of large stands of invasive hogweed. In principle, the effect of grazing is similar to cutting. The animals remove most above ground plant parts, prevent photosynthesis, and thus deplete the energy resources stored in the root. Experience with livestock grazing has been gained mainly from the use of sheep, but the plant is also very palatable to cattle. There are fewer records of goat and horse grazing in relation to the control of invasive hogweed.

'The Hogweed tool' cuts down the stem at a safe distance away from the plant

Photo: Dansk Signal Materiel

Sheep and cattle prefer young and fresh plants, and the most efficient control is obtained by beginning the grazing early in the season when the plants are small.

Photo: C. Nielsen

Sheep and cattle prefer young and fresh plants, and the most efficient control is obtained by beginning the grazing early in the season when the plants are small. In general, the livestock needs a period of time to become used to the hogweed before they regularly eat the plants. However, the animals soon develop a preference for hogweed and large proportions of the plant can be removed. In areas with dense stands of hogweed plants, a single cut is recommended to allow establishment of other plant species since the grazers are less likely to be negatively affected by eating hogweed if the diet is mixed. Tall invasive species of hogweed contain chemicals that cause inflammation of the skin and any mucus-secreting membrane that is or can be exposed to light, e.g lips, nostrils and the membrane covering the eyeball and undersurface of the eyelid (see chapter 7 Public health hazards and safety instructions). Bare and unpigmented skin is particularly susceptible whereas densely pigmented and hairy surfaces are more resistant. Choosing livestock with pigmentation of the bare skin, e.g. black-faced sheep, can reduce inflammation of any mucus-secreting membranes. A symptom of poisoning in the grazers is skin inflammation and blistering around the mouth, nostril, eyes and ears, and potentially the udders and the skin between the anus and the genital organs. Affected animals must be removed from the field temporarily. Clinical studies showed a reduced fecundity after oral application of furanocoumarins. However, this phenomenon has not been reported so far for grazing animals.

The grazing pressure is adjusted according to the density of the stand and the growing season. It is recommended to use a dense regime of animals in spring (20-30 sheep/ha), and reduce grazing pressure at the end of June (5-10 sheep/ha) when the plant is weakened and most of the plant biomass has been removed. Grazing is a cheap method when large fenced areas can be established but should also be considered for smaller stands if neighbouring areas are grazed and livestock can be relatively easily transferred for shorter periods. An example of costs of controlling Giant Hogweed by sheep grazing is presented in Box 1. If possible, the fenced area should not only include the colony of tall invasive species of hogweed but also the surrounding area where seed dispersal may have taken place. Over time,

grazing promotes a dense sward of grazing-tolerant species and limits the amount of suitable ground in which hogweed seeds can germinate and become established. The livestock requires daily inspection and access to water and additional supplements of nutrients (e.g. minerals) may be necessary. Inspections of fences should be conducted periodically in order to maintain them.

Herbicides

Results of numerous trials have demonstrated the susceptibility of invasive hogweeds to systemic herbicides such as glyphosate and triclopyr, and the application of chemicals is considered effective and cheap. Triclopyr has no effect on germinating grasses and is useful in controlling a range of broad-leaved species such as Giant Hogweed. Glyphosate is also registered for use, including locations close to water, and is currently the only herbicide approved for control of tall invasive species of hogweed in all European countries. However, the use of herbicides in, for example, fallow fields or in the vicinity of water could be restricted by national legislation. National rules and guidelines should be consulted before any herbicidal application is undertaken. Policies at the EU level aim to reduce the amount of pesticides and protect the groundwater quality from potential sources of pollution such as herbicides. If herbicides are to be applied it is strongly recommended that the plants are treated early in spring when they have reached a height of 20-50 cm and access to the centre of the colony is still possible for ope-

Box 1. Costs of livestock grazing for control of tall invasive hogweeds

Costs of controlling Giant Hogweed by livestock grazing can be separated into establishment and running costs:

Establishment costs:
Fencing (lifespan of 10 years)
Shelter/housing
Water supply
Purchases of animals

Running costs:
Maintenance of fencing, periodic inspection
Daily inspection of animals
Moving of animals between fenced areas
Additional fodder
Veterinary inspection and treatment

Other possible expenditures:
Administration
Supplementary cutting of Giant Hogweed plants outside the fencing
Scrub removal, branch pruning, building of stiles

Costs of fencing depend on circumference of the area. Running costs depend on size, number and length of fencing.

Treatment effects of glyphosate when applied once early in the growing season (late April). The photograph was taken one month after the treatment

Photo: C. Nielsen

rators. A follow-up spraying may need to be carried out before the end of May when seedlings, which have germinated after the first treatment should be treated. An overall spray with glyphosate at the dose recommended on the product label by the manufacturer is an effective treatment for invasive hogweed but only at the expense of all other vegetation, which however is sparse under tall invasive hogweed colonies. Spraying should be done in dry and calm weather. In amenity areas, areas with mixed vegetation and nature reserves, spraying should be carried out using a nozzle that constricts the spray, weed-wiper or a brush. Otherwise, a non-chemical treatment is preferable.

Other methods

In addition to herbicidal control, the use of salt, household ammonia, heating oil and other chemicals for the control of invasive hogweed have been reported from time to time. These control methods are not recommended as the efficacy seldom has been proved and their application to the invasive weed may change conditions of the soil and watercourses with negative consequences. The use of cryotechnology against weeds such as invasive hogweeds has recently been patent applied. The low temperatures of cryogenic liquids cause severe tissue damage to the plants and may have potential as a control method but the application technique is still in development.

Combinations of different control methods can be more efficient than using a single method. For example, if an early glyphosate spraying of a large colony has resulted in minor regrowth, an additional treatment of mowing or cutting by scythe of the surviving plants can replace a second glyphosate application. In contrast, a colony that has grown too tall and dense is unsuitable to treat efficiently with glyphosate due to the protection of smaller plants provided by larger mature plants and the health hazard which the plants represent to operators. If the plants are cut down to ground level, a follow-up spot treatment of regrowth with hand held equipment is preferable.

Table 4. Recommended control options

Population size	Control options	Estimated time effort	Notes
Few plants, 5-100 individuals	Root cutting	100 plants/hour (plants in their second growing season)	Labour expensive, but an effective method
	Mechanical cutting	100-200 plants in less than one hour when using a scythe	Less labour expensive than root cutting, but also less effective
	Chemical control, spot treatment	100-200 plants/hour	Needs to comply with national rules and guidelines for herbicide use
Small colony, 100-1,000 plants	Root cutting	100 plants/hour (plants in their second growing season)	Labour expensive, but efficient
	Mechanical mowing or cutting	Mechanical mowing by flail mower: 0.25-1 ha/hour Mechanical cutting by scythe: High density: 1,500 plants/hour Medium density: 1,000 plants/hour Low density: 500 plants/hour	Machinery is required
	Chemical control	300 m^2/hour	Hand-held equipment
	Grazing	(see below for scale of effort)	Should be considered if neighbouring areas are grazed
Large colony, >1,000 plants	Ploughing, milling or mechanical mowing	Mechanical mowing by flail mower: 0.25-1 ha/hour	Machinery is required. Not all stands are accessible for heavy machinery
	Chemical control	0.5-1 ha/hour	Machinery is required
	Grazing	1,000 hours per year for daily inspection and moving of 170 sheep distributed on 10 different areas	Total cost depends on the price of fencing, maintenance and inspection of the animals

Box 2. Comparison of estimated costs of different control methods.

In order to control a number of areas infested with Giant Hogweed along the stream Seest Mølleå, Denmark, sheep grazing was considered and the estimated costs of purchase and maintenance of the fences over 10 years were estimated.

Area description	2 fenced areas, one fence with no running costs 4 areas: expenses for materials and putting up new fences, the sheep farmer is responsible for maintenance 7 areas: new fences and maintenance	
	Total area:	9.18 ha
	Number of Giant Hogweed plants:	111,800
Cost of fencing	Fencing options:	
	4-wire electric wire fencing:	1.34 Euro/m
	Steel fence:	2.69 Euro/m
	Cost of fencing includes fencing posts and putting up the fence. Steel fences are often preferred as less maintenance and inspection are required.	
Maintenance	Yearly inspection of the fence:	0.20 Euro/m
	Other inspections:	0.07 Euro/m
Total costs	The total costs include the steel fence and maintenance of the fence over 10 years: 21,068 Euro. Costs per year:	**2,107 Euro**

Additional expenses of sheep grazing include shrub removal, branch pruning, purchases of animals, veterinarian fees, shelter, fodder etc. (see Box 1). Based on the estimated time for control given in Table 4 and cost of labour of 33 Euro/hour, the price of other control options for the first year of control can be calculated:

Root cutting
Estimated time for control: 100 plants/hour
111,800 plants / 100 plants/hour = 1,118 h
Year 1: one treatment at 1,118 h × 33 Euro/h = **36,894 Euro**

Mechanical control by scythe
Estimated time for control: 500 plants/h
111,800 plants / 500 plants/h = 224 h
Year 1: Three treatments: 672 h × 33 Euro/h = **22,176 Euro**

Chemical control by hand held equipment
Estimated time effort: 300 m^2/h
91,800 m^2 / 300 m^2/h = 306 h
Year 1: two treatments at 612 h × 33 Euro/h = **20,196 Euro**

Notes:
The estimated costs are based on Danish prices in 2002. Checking/inspection of the plants post treatment is not included in the costs and transportation of animals between the areas may increase the time taken to achieve control. The time effort for control in the following years has not been evaluated. One treatment of root cutting is usually sufficient to kill the plant, however, new plants may germinate and further inspection will be needed. The costs of chemicals and equipment are not included in the price of chemical control.

10 Revegetation

Control of *H. sosnowskyi* in Latvia by four times cutting and sowing of grass mixture. The experimental plot to the right shows the natural regrowth

Photo: O. Treikale

When the eradication of an invasive weed from an area has been successful, the land is left denuded and vulnerable to soil erosion and the re-introduction of invasive weeds. The best response is to initiate regular land use and in particular crop production or grassland management. The establishment of a cover crop, for example, would protect the land from erosion and the reintroduction of the invasive weed, e.g. Giant Hogweed, from populations elsewhere.

In parts of Europe, *Heracleum sosnowskyi* has been grown as a crop for silage production. After this practice was given up, the plant established itself in very extensive and dense stands taking advantage of widespread abandonment of arable land and a significant reduction in the abundance of grazing animals. Experiments in these former fields now infested with *H. sosnowskyi* have resulted in the following recommendations for the restoration of pastures following the control of *H. sosnowskyi.* The management is especially suitable for former agricultural land that has not been cultivated for several years and other areas set aside from agriculture with heavy infestations of invasive hogweeds. The integrated methods used include mowing/cutting, chemical control, soil cultivation and sowing of grass mixtures.

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.

After soil cultivation, grass mixtures should be sown at high seed densities (4,000 emerging seedlings/ m^2). Native grass species and cultivars must be chosen that have proven to be competitive, produce dense swards, are suitable for growing in mixtures, and make good growth after repeated cutting. Examples of grass mixtures that have proven suitable are: *Dactylis glomerata, Festuca rubra* (50:50), and *Lolium perenne, Festuca rubra, Poa pratensis* (12:35:53). A selective herbicide suitable for broad-leaved weeds in the developing grass sward (including newly emerged seedlings of invasive hogweed species) may be used as a single application during the vegetative period.

In natural habitats, e.g. along riversides, it is not advisable to make herbicide treatments prior to the sowing of grass mixtures. The creation of a strong competitive plant community for the depression of hogweed and stability of the soils against erosion is achieved by additional cutting treatments and increasing sowing rates of grass mixtures.

In places with high densities of hogweed, above ground cutting of all plants in the spring is recommended after the over-wintering plants have re-sprouted. Sowing grass mixtures at increased sowing rate and with the ability to grow well after frequent cutting is recommended for re-establishment of native grass sward. Seeds may be sown by hand. The best seed for this purpose are those types of grass that are very abundant in the locality, resistant to flooding, well-adapted to the habitat and able to compete with the hogweed. Examples of grass mixtures that have proven suitable are *Dactylis glomerata, Festuca rubra* (50:50), and *Festuca arundinacea, Festuca rubra* (35:65). Frequent cutting of the re-established grass sward is recommended, when the height of hogweed seedlings reaches 20-30 cm.

Heracleum sosnowskyi **along a riverside in Latvia**

Photo: J. Gurkina

Sowing grass mixtures in sandy soils of a floodplain and along riverbanks should be avoided, because the seeds of invasive hogweed species along with other seeds are deposited by flooding. The seeds are retained in the grass sward and will germinate well in spring. In such places only root cutting and cutting of the plants before flowering can be recommended for the control of invasive hogweeds.

Following these recommendations including follow-up mowing, the competitive effect of the sown grass mixtures will be seen on the re-growth of the hogweed. By frequent cutting of naturally established grass species, mainly *Elymus repens* and *Poa pratensis*, a highly competitive grass sward will be achieved that reduces the density of the invasive plant significantly. The diversity of such a grass sward will increase gradually as native broadleaf species colonise the sward. The speed of this increase depends on accessibility of seed sources (e.g. from nearby natural meadows). After revegetation is complete, the restored areas are usable for agricultural use or as recreational space.

Afforestation is a special case of a cover crop strategy that could be applied against such weeds as tall invasive hogweeds. When windfall or tree felling creates openings in beech forest, for example, the gaps could be colonised by hogweed species. As the forest re-colonises the gap, it will gradually shade out the invasive hogweeds. The ability to shade depends on the tree species. Beech *(Fagus sylvatica)* is very capable of shading out tall hogweeds whereas Firs *(Abies* species) and Willows *(Salix* species) are considered less capable. Also there is variation among the different tall invasive hogweed species with respect to shade tolerance: *Heracleum mantegazzianum* is less shade tolerant than *H. sosnowskyi*.

A gap in the forest is colonised by invasive hogweeds. The trees will gradually shade out the plants

Photo: H.P. Ravn

11 Planning a management programme

We have provided information on the biology and management options in this short manual. Here we offer some advice to land managers on how to use this information.

Firstly, clearly define objectives. What level of control is required over what area? Is the objective eradication, containment or just to keep populations down? In the case of tall invasive hogweeds, eradication of small and moderate infestations should be quite feasible using the methods presented in this manual. The scale of operation might be a garden, a nature reserve, a park, a valley, a watershed, a country, or group of countries.

Is the area to be managed isolated – i.e. once the local control objective is achieved, will invasive hogweeds continue to colonise your land, for example, from neighbouring land or from up stream? If so, before investing resources in managing the problem on your land, it would be worthwhile linking with those responsible for your source areas to put together a co-ordinated plan. The most effective control programmes will be those that address the problem over the whole of an ecological unit that will not be easily colonised from other areas. This will often mean taking a watershed approach.

Another question to consider is whether to prioritise large dense stands that produce enormous numbers of seeds, or small outlier plants or patches likely to expand into dense infestations. If tackling both is not feasible due to resource limitation, then priorities need to be set. In general it is probably advisable to clear out the small colonizer patches first before tackling the large dense patches. The rate of expansion of the former will be more rapid than the latter, if the conditions are suitable for invasion. Remember, small patches need different control methods to those needed for managing a large dense stand. If a stand borders a river it is advisable to start the control from the river to stop spread of seeds in the water.

The section on Preventive measures, early detection and eradication identifies some of the special requirements to be able to respond to new infestations with local eradication. Once the objective and area of operation are clear, and the availability of resources assessed (money, labour, equipment), the control methods to be used can be identified and the implementation strategy will follow.

Photo: J. Hattendorf

12 Literature

Andersen, U.V. and B. Calov (1996): *Long-term effects of sheep grazing on giant hogweed (*Heracleum mantegazzianum*). Hydrobiologia, 340: 277-284.*

Caffrey, J.M. (1994): *Spread and management of* Heracleum mantegazzianum *(Giant Hogweed) along Irish river corridors.* In *L.C. de Waal, L.E. Child, P.M. Wade and J. H. Brock (eds.), Ecology and Management of Invasive Riverside Plants. John Wiley & Sons Ltd: 67-76.*

Caffrey, J.M. (1999): *Phenology and long-term control of* Heracleum mantegazzianum. *Hydrobiologia, 415: 223-228.*

Child, L.E., and L.C. de Waal (1997): *The use of GIS in the management of* Fallopia japonica *in the urban environment.* In: *J.H. Brock, M. Wade, P. Pysek and D. Green (eds.), Plant Invasions: Studies from North America and Europe. Backhuys Publishers, Leiden: 207-220.*

Dodd, F.S., L.C. de Waal, P.M. Wade and G.E.D. Tiley (1994): *Control and management of* Heracleum mantegazzianum *(Giant Hogweed).* In *L.C. de Waal, L.E. Child, P.M. Wade and J. H. Brock (eds.), Ecology and Management of Invasive Riverside Plants. John Wiley & Sons Ltd: 111-126*

Faurholdt, N. and J.C. Schou (2004): *Nordiske skærmplanter. Dansk Botanisk Forenings Forlag, Copenhagen, 166 pp. [*In Danish*: Nordic Umbelliferous Plants].*

Freeman, K., H.C. Hubbard and A.P. Warin (1984): *Strimmer rash. Contact Dermatitis, 10: 117-118.*

Gökbulak, F. (2003): *Comparison of growth performance of* Lolium perenne *L.,* Dactylis glomerata *L. and* Agropyron elongatum *(Host.) P. Beauv. for erosion control in Turkey. Journal of Environmental Biology, 24: 45-53.*

Grossheim, A.A. (1967): *Flora of Caucasus. Second edition, vol. VII, Umbelliferae - Scrophulariaceae. Leningrad, Nauka.*

Gunby, P. (1980): *Keep away from that 'tree,' folks! Journal of the American Medical Association, 244: 25-96.*

Haggar, R.J., J. Johnson, S. Peel, R.W. Snaydon and R.S Taylor (1982): *Weed control in grassland.* In *H.A Roberts (ed.), Weed Control Handbook: Principles. Blackwell, Oxford.*

Hüls, J. (2005): *Populationsbiologische Untersuchung von* Heracleum mantegazzianum *Somm. et Lev. in Subpopulationen unterschiedlicher Individuendichte. Dissertation, University of Giessen [*In German*].*

Håkansson, S. (2003): *Weeds and Weed Management on Arable Land: An Ecological Approach. CABI Publishing, UK.*

Kavli, G. A. and G. Volden (1984): *Phytophotodermatitis. Photodermatology 1: 65-75.*

Lovell, C.R. (1993): *Plants and the Skin. Oxford, Blackwell Scientific Publications.*

Lundström, H. and E. Darby (1994): *The* Heracleum mantegazzianum *(Giant Hogweed) problem in Sweden: Suggestions for its management and control.* In *L.C. de Waal, L.E. Child, P.M. Wade and J. H. Brock (eds.), Ecology and Management of Invasive Riverside Plants. John Wiley & Sons Ltd: 93-100.*

Mandenova, I.P. (1950): *Caucasian species of the genus* Heracleum. *Tbilisi, Akademia Nauk Gruzinskoy SSR, 103 pp.*

Mandenova, I.P. (1951): Heracleum. In *B.K. Shishkin (ed.), Flora of USSR. Akademia Nauk USSR, Moskva, Leningrad, p. 223-259.*

Ochsmann, J. (1996): Heracleum mantegazzianum *Sommier et Levier (Apiaceae) in Deutschland - Untersuchungen zur Biologie, Verbreitung, Morphologie und Taxonomie. Feddes Repertorium, 107: 557-595 [*In German*].*

Often, A. and G. Graff, 1994: *Skillekarakterer for kjempebjørnekjeks (*Heracleum mantegazzianum*) og tromsøpalme (*H. laciniatum*). Blyttia 52: 129-133 [*In Norwegian: Characteristics separating *H. mantegazzianum* and *H. laciniatum*].*

Okonuki, S. (1984): *World Graminous Plants, Nippon Soda Co. Ltd, Tokyo.*

Otte, A. and R. Franke (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.*

Pathak, M.A. (1986): *Phytophotodermatitis. Clinics in Dermatology, 4: 102-121.*

Pyšek, P. (1991): Heracleum mantegazzianum *in the Czech Republic: the dynamics of spreading from the historical perspective. Folia Geobotanica et Phytotaxonomica 26: 439–454.*

Pyšek, P. and K. Prach (1993): *Plant invasions and the role of riparian habitats – a comparison of four species alien to central Europe. Journal of Biogeography 20: 413–420.*

Pyšek, P. and A. Pyšek (1995): *Invasion by* Heracleum mantegazzianum *in different habitats in the Czech Republic. Journal of Vegetation Science 6: 711-718.*

Pyšek P., M. Kopecký, V. Jarošík and P. Kotková (1998): *The role of human density and climate in the spread of* Heracleum mantegazzianum *in the Central European landscape. Diversity and Distributions 4: 9–16.*

Satsyperova, I.F. (1984): *Borshcheviki flory SSSR – novye kormovye rasteniya. Leningrad, 223 pp [In Russian: The genus Heracleum of the flora of the USSR - new fodder plants].*

Sheppard, A.W. (1991): Heracleum sphondylium *L. Biological flora of the British Isles. Journal of Ecology, 79: 235-258.*

Stace, C. (1991): *New Flora of the British Isles. Cambridge University Press. 1226 pp.*

Stewart, F. and J. Grace, (1984): *An experimental study of hybridization between* Heracleum mantegazzianum *Sommier & Levier and* H. sphondylium *L. subsp.* sphondylium *(Umbellifereae). Watsonia 15: 73–83.*

Tappeiner, U. and A. Cernusca (1990): *Charakterisierung subalpiner Pflanzenbestände im Zentralkaukasus anhand von Bestandsstruktur und Strahlungsabsoption. Verhandlungen der Gesellschaft für Ökologie, 19: 768-778 [*In German*].*

Tiley, G.E.D. and B. Philp (1994): Heracleum mantegazzianum *(Giant Hogweed) and its control in Scotland.* In: *L. C. de Waal, L. Child, P. M. Wade and J. H. Brock (eds.), Ecology and Management of Invasive Riverside Plants. Chichester, Wiley & Sons: 101-109.*

Tiley G.E.D., F.S. Dodd and P.M. Wade (1996): *Biological flora of the British Isles. 190.* Heracleum mantegazzianum *Sommier et Levier. Journal of Ecology 84: 297–319.*

Tutin, T.G. (1980): *Umbellifers of the British Isles. B.S.B.I. Handbook No. 2. Botanical Society of the British Isles, London.*

Tutin, T.G., D.M. Moore, G. Halliday and M. Beadle (1986): *Flora Europaea. Vol. 2, Rosaceae to Umbelliferae. Cambridge University Press. 470 pp.*

Williamson, J.A. and J.C. Forbes (1982): *Giant Hogweed (*Heracleum mantegazzianum*): Its spread and control with glyphosate in amenity areas. Proceedings of the 1982 British Crop Protection Conference – Weeds: 967-972.*

Wittenberg, R. and M.J.W. Cock (2001): *Invasive Alien Species: A Toolkit of Best Prevention and Management Practices. CABI Publishing, Wallingford, UK, 228 pp.*

Forest & Landscape

b
UNIVERSITÄT
BERN

CABI Bioscience
A division of CAB International

University of
Hertfordshire

JUSTUS-LIEBIG-
UNIVERSITÄT
GIESSEN

Institute of Botany
Academy of Sciences of the Czech Republic

AAPC