Hygrophila polysperma *is an aquatic plant in the family Acanthaceae. © Dennis Lamczak. CC BY-SA 3.0.*

The management of Indian swampweed (*Hygrophila polysperma*)

Measures and associated costs

Species (scientific name)	*Hygrophila polysperma* (Roxb.) T. Anderson
Species (common name)	Indian swampweed
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Summary of the measures, emphasizing the most cost-effective options.

Hygrophila polysperma is a submerged or emerged growing, perennial aquatic plant. Native to Asia, the species is reported in Europe only from some thermally heated waters. There are no reports of invasive behaviour so far in Europe and only a very small area of the European Union is marginally suitable for establishment, as it is a frost sensitive species (EPPO, 2016). *H. polysperma* grows in both natural and man-made stagnant and running water, marshes, swamps, and wetlands in both its native and introduced range (Nault and Mikulyuk, 2009; Thayer *et al.,* 2017).

Hygrophila polysperma has long been imported and traded in considerable amounts in shops in Europe (Brunel, 2009). However, due to the low risk of the species establishing if introduced into Europe, including in view of projected climate change, the recent risk assessment for the species (EPPO, 2016) does not recommend any phytosanitary measures for the species.

When the species does establish within a broader landscape with suitable habitats, early detection and rapid eradication is critical for limiting the spread of invasive aquatic plants. Early detection could be achieved by incorporating the species in a more comprehensive citizen-science IAS monitoring system in combination with a general public awareness campaign. In addition, new developments in eDNA to detect submerged aquatic plants are promising (Scriver *et al.*, 2015; Matsuhashi *et al.*, 2016). Rapid response to control potential small scale infestations seems to be effective. Physical removal of small patches may be successful through careful and thorough hand-pulling, and can be improved in combination with using benthic barriers. Mechanical control options on *H. polysperma* have not yet been studied in detail.

The main knowledge gap is in biological control, and the identification of a host-specific biological control candidate for this species should be a priority.

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.

Prohibition of import, sale, transport, exchange, breeding and release.

MEASURE DESCRIPTION

Of this species, this is the only measure that will reduce the risk of its potential establishment in the EU. International trade in aquarium plants is the only introduction pathway identified for the species (EPPO, 2016).

EFFECTIVENESS OF MEASURE

While this is the most effective measure for addressing the species pathway of introduction, its effectiveness for *H. polysperma* is questionable, as without a ban on the import, the species has not yet succeeded in establishing in natural areas in the EU (EPPO, 2016). Yet, it is relatively easy to purchase the species in shops or via internet (Nault and Mikulyuk, 2009; The Guardian, 2016). In the United States, where larger areas have climatic conditions which are more suitable, the species is subject to a range of restrictive measures in numerous states and at federal level (Thayer *et al.,* 2017).

EFFORT REQUIRED

In general, considerable effort is needed to train staff, develop identification tools for border control and communicate the measures to stakeholders and the general public.

RESOURCES REQUIRED

The resources required to implement a ban on import and sale of the species have not been quantified, however the infrastructure (such as customs, etc.) already exist within the EU for other species.

SIDE EFFECTS

None known.

ACCEPTABILITY TO STAKEHOLDERS

Banning the trade would have a significant impact on traders of aquarium plants. A wide range of cultivars of this species are in trade. In the UK alone in 2015 ca. 500,000 plants were sold valuing over GBP 500,000 (EPPO, 2016). Import data for the Netherlands amounted to ca. 250,000 units in 2006 (Brunel, 2009). In addition to that, the majority of plants in trade are produced within the EU (pers. comm., van Valkenburg).

ADDITIONAL COST INFORMATION

No information available.

LEVEL OF CONFIDENCE[1]

High.

This assessment is based on the Pest Risk Analysis (EPPO, 2016) and associated modelling.

1 See Appendix

No known unintentional pathways.

MEASURE DESCRIPTION
There are no known unintentional pathways of introduction, and the spreading of the species from one site to another is only via movement of plant fragments downstream and only by early detection and rapid eradication can this issue be addressed. Measures such as targeted public awareness campaigns which have been used for other aquatic invasive alien species would not be cost-effective if targeted on this species as its spread via plant fragments, moved unintentionally by recreation activities etc., would only successfully occur when made to other thermally abnormal rivers which is highly unlikely.

EFFECTIVENESS OF MEASURE
Not Applicable.

EFFORT REQUIRED
Not Applicable.

RESOURCES REQUIRED
Not Applicable.

SIDE EFFECTS
Not Applicable.

ACCEPTABILITY TO STAKEHOLDERS
Not Applicable.

ADDITIONAL COST INFORMATION
Not Applicable.

LEVEL OF CONFIDENCE[1]
Not Applicable.

1 See Appendix

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

Citizen-science.

MEASURE DESCRIPTION

The early detection of invasive alien aquatic plant species is a key factor in the successful eradication of new infestations (Genovesi *et al.*, 2010; Hussner *et al.*, 2017). Early detection in combination with a rapid response is a proactive approach, focussed on the successful management of alien species prior to their establishment. After the early detection of a species, well-coordinated rapid management measurements are required, which must take into account the specific biology and habitat characteristics to achieve the total eradication of the target species (Hussner *et al.*, 2017).

Citizen-science, in combination with a national coordinating body, may well be a suitable approach. Citizen scientists have surveyed for and monitored a broad range of taxa, and also contributed data on weather and habitats reflecting an increase in engagement with a diverse range of observational science. Citizen-science has taken many varied approaches from citizen-led (co-created) projects with local community groups to, more commonly, scientist-led mass participation initiatives that are open to all sectors of society. Citizen-science provides an indispensable means of combining environmental research with environmental education and wildlife recording (Roy *et al.*, 2012). The problem of early detection using citizen-science in the case of *Hygrophila polysperma,* is that it is very difficult to determine the species accurately because of the absence of striking morphological features when not in flower.

EFFECTIVENESS OF THE SURVEILLANCE

Delaney *et al.,* (2008) successfully used the data collected by citizen scientists to create a large-scale standardized database of the distribution and abundance of native and invasive crabs along the rocky intertidal zone in Massachusetts, USA. An assessment of the accuracy of data collected by citizen scientists showed that, depending on experience, between 80 and 95% accuracy in identification was achieved (Delaney *et al.*, 2008). In the case of *H. polysperma* this percentage is likely to be lower, as the species is difficult to identify when not in flower. Accuracy of reported sightings of *Ambrosia artemisiifolia* in the Netherlands also was significantly lower (pers. comm., van Valkenburg).

EFFORT REQUIRED

Roy *et al.,* (2012) state that "Environmental monitoring relies on long-term support in terms of volunteer liaison, data handling, quality assurance, publication and statistical support for measuring trends, requiring the involvement of a professional scientific organisation. The use of volunteers in citizen-science is critical for the success and is supported at a European-level through the SEBI (Streamlining European 2010 Biodiversity Indicators) "public awareness indicator" which reported that over two-thirds of EU citizens report personally making efforts to help preserve nature. The Pan-European SEBI initiative was launched in 2005. SEBI aims to develop a European set of biodiversity indicators to assess and inform European and global biodiversity targets. SEBI links the global framework, set by the Convention on Biological Diversity (CBD), with regional and national indicator initiatives. Many of the headline indicators rely entirely on the availability of monitoring data and particularly datasets on biodiversity developed by volunteer naturalists (Levrel *et al.*, 2010)."

RESOURCES REQUIRED

Integration of accurate citizen-science requires a coordinating scientific or government body. Normally the work would be

Hygrophila polysperma, *native to India, Bangladesh, China and Malaysia, and introduced in some states in the U.S. © Averater. CC BY-SA 4.0.*

funded by research grant funding, or by direct funding of scientific organisations by MS Governments. Annual costs for running citizen-science projects in 2007–2008 were estimated at between €80,000 and €170,000 (Roy *et al.*, 2012).

SIDE EFFECTS

Positive side effects include a potential greater awareness of environmental problems by the public. The active involvement of volunteers is also likely to provide feedback on potential new non-native species.

ACCEPTABILITY TO STAKEHOLDERS

Generally, this technique is accepted by stakeholders, and involvement with research and the scientific community tends to increase acceptance of public funding of such bodies.

ADDITIONAL COST INFORMATION

No information available.

LEVEL OF CONFIDENCE[1]

High.

Citizen-science has been shown to provide significant leverage in observation power, accurate data (depending on experience and training in taxonomic identification and depending on the taxonomic group) and should be encouraged as a valuable tool in the early detection of any invasive alien species in the EU.

Environmental DNA analysis (eDNA).

Hygrophila polysperma. © *Krzysztof Ziarnek, Kenraiz. CC BY-SA 4.0.*

MEASURE DESCRIPTION

One of the most promising options for early detection and ongoing surveillance of aquatic invasive alien plants in general is development of environmental DNA analysis (eDNA) (Scriver *et al.*, 2015; Matsuhashi *et al.*, 2016). The application of eDNA in aquatic systems involves the extraction of DNA from a water sample, and then either screen for individual species using targeted, species-specific molecular markers (active surveillance) or high-throughput sequencing to reveal communities of species (passive surveillance) (Mahon and Jerde, 2016).

EFFECTIVENESS OF THE SURVEILLANCE

While eDNA is widely recognised as a powerful tool to monitor for aquatic animal species, it is still in an experimental phase as far as aquatic plants are concerned (Fujiwara *et al.,* 2016; Matsuhashi *et al.,* 2016).

EFFORT REQUIRED

No detailed information available as it is still in an experimental phase.

RESOURCES REQUIRED

Expertise, facilities and equipment are needed for sample collection, filtration and preservation; DNA extraction (for example, a centrifuge); and the DNA sequencing and analysis. See Mahon and Jerde (2016) for more information.

SIDE EFFECTS

None anticipated.

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ACCEPTABILITY TO STAKEHOLDERS

Impact of the technique is minimal as only water samples are taken.

ADDITIONAL COST INFORMATION

No information available, however a study on the development and validation of eDNA markers for detection of freshwater turtles (native and non-native) found that the cost of detection through traditional survey methods is 2–10× higher than eDNA detection (Davy *et al.*, 2015).

LEVEL OF CONFIDENCE[1]

High.

Although still experimental the published results are available and transparent.

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

Physical removal.

MEASURE DESCRIPTION

This measure including removal of small patches may be successful through careful and thorough hand-pulling. Great care should be taken with such methods since they can cause fragmentation of the plant and therefore increase potential spread (EPPO, 2016). Once removed, it is very likely that regrowth from fragments will occur, despite careful biosecurity arrangements. Therefore, additional monitoring of the managed site will be required on a regular basis after removal.

EFFECTIVENESS OF MEASURE

Hand removal is more cost-effective and more efficient in areas with small, high-density infestations. Eradication may only be feasible in the initial stages of infestation (EPPO, 2014).

EFFORT REQUIRED

In small infestations, manual removal is relatively easily achieved depending on the sediment. Careful hand picking of fragments is necessary in order to avoid fragmentation and spreading.

RESOURCES REQUIRED

The removal of areas of less than 100 m^2 should take no more than one day, with the involvement of at least three people (pers. comm., Newman, J.).

SIDE EFFECTS

None anticipated.

ACCEPTABILITY TO STAKEHOLDERS

This type of mechanical control (hand-pulling) is generally accepted by stakeholders.

ADDITIONAL COST INFORMATION

Early detection and rapid eradication given the costs of management, a prompt response to newly establishing populations will be important to avoid later management costs.

LEVEL OF CONFIDENCE[1]

Medium.

Recently detected infestations may be successfully eradicated through careful and thorough hand-pulling. Great care should be taken with such methods since they can cause fragmentation of the plant and therefore may enhance its spread.

Benthic barriers.

MEASURE DESCRIPTION

Small patches may be successfully controlled by using benthic barriers such as a tarpaulin (EPPO, 2014). Information on how to build a benthic mat can easily be found on the internet (for example, see http://waynecountynysoilandwater.org/wp-content/uploads/Benthic-Mat.pdf).

EFFECTIVENESS OF MEASURE

Benthic barriers may be used in small areas to restrict sun-light by covering the plants, and should be effective in the absence of propagules from other, hydrologically connected populations. However, in situations where propagule pressure is expected, the effect over the long term is not clear as it is expected that after reopening, regrowth of

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macrophytes will occur, including of invasive alien aquatic plants (EPPO, 2014).

EFFORT REQUIRED

Ideally if the infestation is small and can be covered by a single sheet of benthic barrier, it only needs to be applied once.

RESOURCES REQUIRED

Resources required will depend on extent and accessibility of the infestation and the material used (EPPO, 2014; Caffrey and Acavedo, 2007). While the material itself (tarpaulin, with or without PVC frames) is relatively cheap, and rocks can be used to weigh it down, there will be additional costs for installation. In the USA, according to a factsheet produced by the Three Lakes Association (http://3lakes.com), professional installation can cost US$ 10,000–$20,000 per acre, though the ability to reuse the material over several years will reduce the costs. Scuba divers may be needed in deeper water (ca. >6.5 foot) and plots with steep slopes, natural obstructions or heavy plant growth may require additional assistance (see http://www.3lakes.net/wp-content/uploads/2008/02/Benthic-barrier-info-from-NY.pdf).

SIDE EFFECTS

Benthic barriers are not selective. Benthic barriers will impact all target and non-target organisms trapped underneath the barrier.

ACCEPTABILITY TO STAKEHOLDERS

This type of limited use of benthic barriers is generally accepted by stakeholders as the possible negative side effects are of a limited extent and should outweigh the negative impact of a further spread of the invasive species if left uncontrolled.

ADDITIONAL COST INFORMATION

A follow-up survey to monitor for fragments that may have escaped while applying the benthic barrier should be performed for some years (pers. comm., van Walkenburg).

LEVEL OF CONFIDENCE[1]

Medium.

There is no published information on this method being applied for the species. Recently detected infestations may be successfully eradicated by using benthic barriers.

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Measures for the species' management.

Physical control.

MEASURE DESCRIPTION

This consists of hand pulling, raking up, or using various means of machinery operated from the bank or even floating weed cutting boats to control large floating mats of aquatic plants (EPPO, 2014). Using benthic barriers to smother the plants (see *Rapid eradication* sections above) is yet another option that may be used in combination. However, it is important to note that no specific methods have been described for *Hygrophila polysperma*.

EFFECTIVENESS OF MEASURE

Despite the species posing an increasing problem in Florida no detailed information can be found on the efficacy of mechanical control apart from general statements that mechanical control appears to be counterproductive as a result of the regenerative capacity of the species (EPPO, 2016).

EFFORT REQUIRED

No species-specific information is available.

RESOURCES REQUIRED

No species-specific cost for management could be found.

SIDE EFFECTS

Environmental impact is limited when the infestation is small. Hand-pulling control is mostly selective and therefore non-target plants will be not damaged. Mechanical control such as cutting can damage surrounding areas and non-target plants can be affected.

ACCEPTABILITY TO STAKEHOLDERS

Mechanical control of aquatic and riparian weeds is generally accepted by stakeholders, unless considerable damage is seen to be done without any effort to reinstate the area.

ADDITIONAL COST INFORMATION

Once removed, it is very likely that regrowth from fragments will occur, despite careful biosecurity arrangements. Therefore, additional monitoring of the managed site will be required on a regular basis.

LEVEL OF CONFIDENCE[1]

Medium.

There is no published information on this method being applied for the species. Physical control is the only method available for EU countries. More research should therefore be undertaken.

Herbicide control.

MEASURE DESCRIPTION

This method is recommended in some states of the USA for the management of this species. Triclopyr is effective against *H. polysperma* at 3.36 kg/ha (Fast *et al.*, 2009). Flumioxazin, registered since 2011, is recommended under specific conditions at a dose of 220 ppb. It is important to note that EU/national/local legislation on the use of plant protection products and biocides needs to be respected, and none of the active ingredients mentioned here are currently approved for use in or near water in the EU.

EFFECTIVENESS OF MEASURE

Fast *et al.,* (2009) tested various foliar applied herbicides for the control of emergent *H. polysperma*. Triclopyr showed the highest efficiency to control *H. polysperma*, and in combination with other herbicides (2,4-D and/or glyphosate) the efficiency for the control is higher than for the application of Triclopyr alone. Temporary control of both the submersed and immersed forms of *H. polysperma* has been achieved in Florida with endothall, but regrowth occurs 4 to 8 weeks after treatment during peak biomass production, and multiple applications are required to keep populations under maintenance control (CABI, 2015).

EFFORT REQUIRED

Not applicable as the method is not approved.

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RESOURCES REQUIRED
Not applicable as the method is not approved.

SIDE EFFECTS
The herbicides tested for *Hygrophila polysperma* are not currently approved for aquatic use in the EU.

ACCEPTABILITY TO STAKEHOLDERS
Not applicable as the method is not approved.

ADDITIONAL COST INFORMATION
Not applicable as the method is not approved.

LEVEL OF CONFIDENCE[1]
High.
However, none of the active ingredients is currently approved for use in or near water in the EU.

Biological control.

MEASURE DESCRIPTION
H. polysperma is considered as a good candidate for biological control (Cuda and Sutton, 2000)**.** Several insects from the plants native range have been observed feeding on the emergent parts of the plant, and in the introduced range in Florida insects have been observed feeding on the submerged leaves (EPPO, 2016).

Triploid grass carp (*Ctenopharyngodon idella*) have also been tested in Florida as part of an integrated control using also mechanical and chemical methods (Cuda and Sutton, 2000).

EFFECTIVENESS OF MEASURE
Grass carp prefer to eat other aquatic plants, so stocking rates need to be very high (Cuda and Sutton, 2000). To date, no effective other biocontrol organism has been put to the test (EPPO, 2016).

EFFORT REQUIRED
To date no lasting effective biocontrol has been achieved. The initial period of host-specificity testing would take approximately 3 years, after which the agent could be released.

RESOURCES REQUIRED
Usually significant effort is required before release of a biological control agent. The cost of this effort is estimated to be in the region of €350,000 (Paynter *et al.,* 2015).

SIDE EFFECTS
Grass carp prefer other aquatic plants over *Hygrophila*, therefore the effect on non-target aquatic plants will be substantial (CABI, 2015).

ACCEPTABILITY TO STAKEHOLDERS
Socio-economic impacts are rare and often supportive if the problem and solution is explained fully. Careful management of biological programmes is usually necessary, despite the adverse impact of the target weed.

ADDITIONAL COST INFORMATION
The cost of testing established biocontrol agents from other parts of the world in MSs would probably cost around €350,000 (Paynter *et al.,* 2015). The cost/benefit ratio for biological control programmes involving aquatic weeds ranges from 2.5:1 to 15:1 (McConnachie *et al.*, 2003), and up to 4,000:1 (Culliney, 2005). As yet, however, successful biological control programmes on aquatic plants have been applied exclusively on free-floating and emergent-leaved aquatic plants, and this should be borne in mind in any cost estimation.

It should be borne in mind that the release of macro-organisms as biological control agents is currently not regulated at EU level. Nevertheless national/regional laws are to be respected. Before any release of an alien species as a biological control agent an appropriate risk assessment should be made.

LEVEL OF CONFIDENCE[1]
Low.
Grass carp do prefer other plants and work on other potential biocontrol agents has not been initiated so far.

1 See Appendix

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Appendix

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 (for example 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 solely on opinion; this is for example the case of a novel situation where there is little evidence on which to base an assessment.

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