Information on measures and related costs in relation to species included on the Union list - *Myriophyllum heterophyllum* and *Myriophyllum aquaticum*

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Date of completion: 25/06/2019

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<table>
<thead>
<tr>
<th>Species (scientific name)</th>
<th><em>Myriophyllum heterophyllum</em> Michx. and <em>Myriophyllum aquaticum</em> (Vell.) Verdc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species (common name)</td>
<td>Broadleaf Watermilfoil and Parrot’s Feather</td>
</tr>
<tr>
<td>Author(s)</td>
<td>Jonathan R. Newman, Waterland Management Ltd, Gainsborough, DN21 4NE, UK</td>
</tr>
<tr>
<td></td>
<td>Manuel A. Duenas, NERC Centre for Ecology &amp; Hydrology, Wallingford, UK</td>
</tr>
<tr>
<td>Date Completed</td>
<td>25/06/2019</td>
</tr>
<tr>
<td>Reviewer</td>
<td>Andreas Hussner, Duisburg, Germany</td>
</tr>
</tbody>
</table>

**Summary**

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

*Myriophyllum heterophyllum* (Haloragaceae) is a perennial submerged macrophyte species native to the eastern United States. The plant is present in Austria, Belgium, France, Germany, Hungary, the Netherlands, Spain, Switzerland and Croatia (EPPO, 2016; Jasprica et al., 2017). It is still absent from many Member States (MS), but there is a high risk of further introductions and spread. The species could establish all over Europe, and climate change is likely to increase the potential invasion area (Newman, 2014). *Myriophyllum aquaticum* (Haloragaceae) is an emergent aquatic macrophyte with both...
submersed and emergent growth forms (Wersal et al., 2013). When stems of *M. aquaticum* reach the water’s surface, they continue to grow horizontally and vertically (Xie et al., 2013), creating thick mats that completely cover the surface (Smith, 2008). *M. aquaticum* has established solely from vegetative reproduction (Smith, 2008). It is established in Belgium, Corsica, France, Germany, Great Britain, Ireland, Italy, Portugal and Spain (DAISIE, 2019), and in Austria, Hungary, Luxembourg and the Netherlands (Sundseth, 2017). *M. heterophyllum* and *M. aquaticum* can be distinguished by their flowers and leaves: *M. aquaticum* has white flowers, and *M. heterophyllum* has reddish flowers. *M. aquaticum* emergent leaves are blue or bright green, deeply dissected, with a feathery appearance (Wellendorf, 2008) and *M. heterophyllum*’s are bright green, lanceolate, and toothed (EPPO, 2016).

The control of these species is difficult once they have become established. Therefore, to prevent introductions into unaffected MS or further spread into areas where these species are not yet present, it is important to act at the earliest stage of invasion, so as to avoid costs linked to managing the species when widely established. Containment and control are likely to be costly, which reinforces the need for preventive action. If biosecurity and quarantine measures are routinely implemented, and combined with biosecurity awareness campaigns, the rate of further range expansion into uncolonised systems will likely be reduced, as the principal mechanism of spread is human-mediated.

Early detection and treatment is critical for limiting the spread of invasive aquatic plants (Moody & Les, 2010). As with most other invasive alien species, the best way to deal with the threat posed by *Myriophyllum* species to biodiversity and society is through a combination of preventative measures, early detection and rapid response to new incursions. Early detection of new introductions is best achieved by using a well-coordinated citizen science programme, combined with public awareness campaigns to identify the species. Another good option, which is starting to be used for the early detection and surveillance of aquatic invasive plants, in general, is the development of eDNA analysis (Scriver et al., 2015).

Physical removal (manual harvesting) of small patches of *Myriophyllum* spp. may be successful for rapid eradication of the species, through careful and thorough hand-pulling, and improved in combination with the Hydro Venturi system (high-pressure water jet). Nevertheless, removal is a very intensive process, so efforts should be focused on preventing introductions into areas that are not currently invaded (e.g. for *M. aquaticum*; Kelly & Maguire, 2009).

Long-term management of the species should only be used as a last resort and total eradication after the species has extensively established is unlikely. Mechanical control of *Myriophyllum* spp. will promote dispersal, spread and establishment in new areas, as these species can spread readily through fragmentation. Therefore, this measure is not advised, unless an area is entirely invaded by plants at a very early stage of invasion (Delbart et al., 2012). Lightproof barriers and hand-removal methods are the most effective management techniques (Bailey & Calhoun, 2008). Efficient biological control is not yet established for *M. heterophyllum*, and for *M. aquaticum* further research is needed to improve the effectiveness of the current biological controls.
**Prevention of intentional introductions and spread** – measures for preventing the species being introduced intentionally. **This table is repeated for each of the prevention measures identified.** If the species is listed as an invasive alien species of Union concern, this table is not needed, as the measure applies anyway.

| Measure description | Globally, *Myriophyllum* species, like most other invasive aquatic plants, have been introduced intentionally through human-mediated dispersal, mainly through international aquarium and horticultural trade, which are the only intentional introduction pathways identified for *M. heterophyllum* (EPPO, 2015) and *M. aquaticum* (Guillarmod, 1979; Orchard, 1981), and probably the main pathways of introduction in the EU (Brunel, 2009).

As the species is listed as an invasive alien species of Union concern, the following measures will automatically apply, in accordance with Article 7 of the EU IAS Regulation 1143/2014:

Invasive alien species of Union concern shall not be intentionally:

(a) brought into the territory of the Union, including transit under customs supervision;
(b) kept, including in contained holding;
(c) bred, including in contained holding;
(d) transported to, from or within the Union, except for the transportation of species to facilities in the context of eradication;
(e) placed on the market;
(f) used or exchanged;
(g) permitted to reproduce, grown or cultivated, including in contained holding; or
(h) released into the environment.

Also note that, in accordance with Article 15(1) – As of 2 January 2016, Member States should have in place fully functioning structures to carry out the official controls necessary to prevent the intentional introduction into the Union of invasive alien species of Union concern. Those official controls shall apply to the categories of goods falling within the Combined Nomenclature codes to which a reference is made in the Union list, pursuant to Article 4(5).

Therefore measures for the prevention of intentional introductions do not need to be discussed further in this technical note.
**Prevention of un-intentional introductions and spread** – measures for preventing the species being introduced un-intentionally (cf. Article 13 of the IAS Regulation). This table is repeated for each of the prevention measures identified.

<table>
<thead>
<tr>
<th>Measure description</th>
<th>Biosecurity and quarantine measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide a description of the measure, and identify its objective</td>
<td>Little is known about the reproductive biology of <em>M. heterophyllum</em>, but many fertile specimens appear to contain viable seeds (Les &amp; Mehrhoff, 1999); the principal means of reproduction is non-sexual via fragmentation, although the stems are quite stout and so do not fragment as readily as many other submerged species (EPPO, 2016). All <em>M. aquaticum</em> plants outside the native range have been female, reproducing solely by fragmentation and vegetative reproduction (Stace, 1997). The stems readily fragment by mechanical actions (Orchard, 1981) and natural fragmentation is low (Heidbüchel et al., 2016). <em>M. aquaticum</em> shows a high regeneration capacity (Xie et al., 2010, 2013), such as regeneration from single leaves (Hussner, 2009) and the ability to form new shoots from single nodes. <em>M. aquaticum</em> increases the regeneration capacities of emerged plants with the increase of water nutrients, whereas <em>M. heterophyllum</em> has lower regeneration capacity (Heidbüchel &amp; Hussner, 2019), as this species has more regeneration in sediment by roots (Kuntz et al., 2014). <em>M. aquaticum</em> shows a high tolerance to different water levels (Hussner et al., 2009), whereas <em>M. heterophyllum</em> is able to maintain the function of the photosynthetic apparatus at high water loss; this capacity allows the extension of fragment viability (Heidbüchel et al., 2019). This ability to survive in different conditions makes <em>M. aquaticum</em> a successful hitchhiker, spreading via the movement of boats and trailers (Smith, 2008) and through the transportation of contaminated materials (e.g. stocked fish; Guillarmod, 1979). As such, the likelihood of the species entering the EU is based on association with boating, angling and other water activities (e.g. Anderson et al., 2014b). This includes the import of used boats from outside the EU or between EU countries. No specific data are available on the movement of boats, boat trailers, boat engines, angling gear and other items used in water activities between countries; however, it is considered moderately likely that the organism can enter by this pathway (Millane &amp; Caffrey, 2014). <em>M. heterophyllum</em>’s tolerance of desiccation means that fragments are likely to remain viable for prolonged periods of time, also allowing its spread as a hitchhiker via human activities (Barnes et al., 2013; EPPO, 2015). The importation of stocked fish is also a pathway of unintentional introduction for <em>M. aquaticum</em>, through the transport of contaminated materials. This was the pathway of introduction of the species into South Africa, thorough trout hatcheries (Guillarmod, 1979). Biosecurity measures to reduce the risk of unintentional introductions of the species attached to boats and water-sport equipment, and quarantine measures for aquatic animals imported into the EU, should be implemented at borders and elsewhere (CABI, 2019).</td>
</tr>
</tbody>
</table>
For example, biosecurity measures recommended by the UK “Check, Clean and Dry” (GB Non-Native Species Secretariat, 2017) campaign include immersion of materials in hot water (45 degrees C) for 15 minutes, although to achieve nearly complete mortality of the species the time of treatment under that temperature should be one hour (Anderson et al., 2015). Shannon et al. (2018) recommend 50 degrees C immersion for a minimum of 5 minutes to achieve high mortality of the propagules and, for 100% mortality, immersion in water at 60 degrees C with 1-minute exposure.

The use of direct steam exposure for 10 seconds has induced substantial fragment degradation in different invasive macrophytes (Crane et al., 2019). Another potential biosecurity agent is aquatic disinfectant. Some commercial disinfectants have been observed to reduce growth rates and decrease shoot and root production at the fragmentary propagules in some aquatic invasive macrophytes (Cuthbert et al., 2018, 2019). Desiccation has also been tested as a biosecurity measure, but is unlikely to prevent the spread of plant fragments (Coughlan et al., 2018), as e.g. *M. heterophyllum* is able to maintain the function of the photosynthetic apparatus at high water loss, which can extend fragment viability (Heidbüchel et al., 2019).

If this measure is applied in areas other than border controls (e.g. water recreation areas), it can also be applied for the prevention of secondary spread of *Myriophyllum* species, and should be combined with the measure described in the following table.

<table>
<thead>
<tr>
<th>Scale of application</th>
<th>At nationwide level.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness of the measure</td>
<td>Effectiveness of measures</td>
</tr>
<tr>
<td>Rationale:</td>
<td>There are successful biosecurity inspections of boats and fishing equipment (combined with public information campaigns) already in place, as per the “Check, Clean and Dry” Campaign in the UK (GB Non-Native Species Secretariat, 2017) and other regional information portals (EUBARnet, 2013). However, if these measures are not implemented by all countries, they will not be effective, as the species could spread from one country to another (EPPO, 2015).</td>
</tr>
<tr>
<td>Effort required</td>
<td>Biosecurity and quarantine measures need to be implemented in the long term.</td>
</tr>
<tr>
<td>Resources required</td>
<td>Resources needed to implement biosecurity and quarantine measures at border controls include staff (who need specific training) and the correct facilities and materials to undertake these measures. Ability by the relevant competent authorities at points of entry to recognise and identify <em>Myriophyllum</em> species is limited, or non-existent, at present. <em>Myriophyllum</em> species are very similar in foliage and may be difficult to differentiate accurately (Aiken, 1981; Thum et al., 2006), because of their high phenotypic plasticity. Therefore, in addition to the existing requirement for a phytosanitary certificate by the exporting country, confirmation of the correct identification and labelling of the species should be required. Molecular DNA barcoding has been developed for <em>M. heterophyllum</em> (Ghahramanzadeh et al., 2013) to confirm the presence of the species in trade and from unidentified wild populations; for <em>M. aquaticum</em>, identification of the species using sequences of nuclear ribosomal DNA for delimitation from other related species has been developed (Shah et al., 2014). Considerable effort is required to train border and customs inspectors in plant identification. This is an ongoing requirement and is estimated at c. €100,000 per MS per annum (based on the cost of training three customs staff for one week and monitoring imports on a country-by-country basis using expert identification skills at national institutes). It is estimated that three trained staff at the main port of entry to the EU (i.e. the Netherlands) would be sufficient to reduce imports significantly.</td>
</tr>
<tr>
<td>Side effects (incl. potential) – both positive and negative</td>
<td>For each of the side effect types please select one of the impact categories (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.</td>
</tr>
<tr>
<td>Environmental effects</td>
<td>Positive</td>
</tr>
<tr>
<td>Social effects</td>
<td>Positive</td>
</tr>
<tr>
<td>Economic effects</td>
<td>Positive</td>
</tr>
</tbody>
</table>

**Rationale:**
A positive side effect could be that other aquatic invasive plants may be detected and prevented from spreading, if these measures are implemented.

| Acceptability to stakeholders | Acceptability to stakeholders | Acceptable | Neutral or mixed | X | Unacceptable |
| Acceptability to stakeholders | Acceptable | Neutral or mixed | X | Unacceptable |

**Rationale:**
Please select one of the categories of acceptability (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.

The suggested measure, if implemented in areas outside of border controls, could have a related impact on recreational water activities and their users, e.g. by forcing them to clean and check their materials and gear, therefore potentially facing opposition by some stakeholders.

| Additional cost information | Additional costs for MS include the costs of monitoring and reporting, and further assessment of management requirements. These can usually be included within the normal activities of regulatory bodies or nature conservation organisations. The cost of inaction should be greater than the cost of implementing prevention methods, due to the difficulty of eradication of this species once established. |

| Level of confidence on the information provided |

| Inconclusive | Unresolved | Established but incomplete | X | Well established |

Rationale:
Biosecurity measures are important tools to stop the unintentional introduction of invasive aquatic plants, with positive results having been shown in the countries in which they have been implemented.

### Prevention of secondary spread of the species

- measures for preventing the species spreading once they have been introduced (cf. Article 13 of the IAS Regulation). This table is repeated for each of the prevention measures identified.

| Measure description | Biosecurity awareness campaigns |

Vegetative reproduction is the main mechanism of spread for *M. heterophyllum*, as seed production has not been observed in Europe yet (Fritschler, 2007; Hussner, 2010). Similarly, spread of *M. aquaticum* occurs principally by
vegetative fragmentation induced mainly by human-related disturbance, and through the dispersal of rhizomes and stem fragments (GISD, 2015). The stems of *M. aquaticum* are brittle and fragment readily (Orchard, 1981). The plants are capable of regenerating rapidly from small fragments (Xie et al., 2010, 2013) and are highly tolerant of desiccation (Hussner & Champion, 2011). The plant does not auto-fragment and viable fragments typically arise from some kind of mechanical disturbance. It takes a piece only 5 mm long with a node to begin a new colony (Kane et al., 1991). *M. aquaticum* shows a high regeneration capacity and the ability to form new shoots from single nodes; it also shows regeneration from single leaves (Hussner, 2009).

There is no evidence that *M. aquaticum* can be dispersed by natural vectors such as wind, birds or animals (Michigan Department of Agriculture and Rural Development, 2015), but the plants can be transported by water (e.g. Anderson et al., 2014b), as the fragments are capable of floating in the water column for weeks before settling and rooting (Sidorkewicj et al., 2000; Xie et al., 2010), and for up to six months (Xie et al., 2013). Tough rhizomes of this species can survive long distances in water (Smith, 2008) and can remain viable for one year if kept under moist conditions (Sytsma & Anderson, 1993b). Free-floating rhizomes and stem fragments of *M. aquaticum* with adventitious roots have extremely high survival rates (Xie et al., 2010, 2013) and facilitate their long-distance dispersal capacity.

Therefore, these species can spread within and between watersheds, easily transported through contaminated recreational equipment, e.g. boats, boat trailers, angling gear and other equipment (e.g. Anderson et al., 2014b; Millane & Caffrey, 2014). Plant fragments attached to ships or boats have been responsible for the spread of non-indigenous milfoils (Les & Mehrhoff, 1999), and the same has been observed in the Nile River, Egypt for *M. aquaticum* (Springuel & Murphy, 1991).

Human-assisted unintentional spread is one of the main causes of dispersal for *M. heterophyllum* in the USA (Green Mountain Conservation Group, 2017). The potential for long-distance spread of *M. heterophyllum* is high because the species is very tolerant of desiccation (Barnes et al., 2013) and the harvested shoots can even grow in a small terrestrial form when disposed of (A. Hussner, pers. comm.), meaning that hitchhiker fragments are likely to remain viable for prolonged periods of time, allowing its spread (EPPO, 2015).

Preventative efforts to avoid secondary spread of these species should be focused on implementing biosecurity awareness campaigns - combined with imposing the biosecurity protocols mentioned in the table above -, directed at boat owners, anglers and people practising aquatic sports, in order to reduce the likelihood of them inadvertently spreading the species through water recreational activities (Anderson et al., 2014b). For further details on the biosecurity measures available to prevent the spread of the plants, see the table on ‘Prevention of unintentional introductions and spread’ above.
<table>
<thead>
<tr>
<th>Scale of application</th>
<th>At nationwide level.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness of the measure</td>
<td><strong>Effectiveness of measures</strong></td>
</tr>
<tr>
<td>Rationale:</td>
<td>Public information campaigns, such as the “Check, Clean and Dry” campaign in the UK (GB Non-Native Species Secretariat, 2017) and other regional information portals (EUBARnet, 2013), are already being implemented with success.</td>
</tr>
<tr>
<td>Effort required</td>
<td>Public awareness campaigns need to be run in the long term.</td>
</tr>
<tr>
<td>Resources required</td>
<td>Aquatic biosecurity programmes in New Zealand cost NZD $0.06 for every water user reached by the biosecurity message (Anderson et al., 2014a).</td>
</tr>
<tr>
<td>Side effects (incl. potential) – both positive and negative</td>
<td><strong>Environmental effects</strong></td>
</tr>
<tr>
<td>Rationale:</td>
<td>Awareness campaigns will raise general public awareness of the problems caused by aquatic invasive species and might help detect and prevent the spread of other IAS.</td>
</tr>
<tr>
<td>Acceptability to stakeholders</td>
<td><strong>Acceptability to stakeholders</strong></td>
</tr>
</tbody>
</table>
e.g. impacted economic activities, animal welfare considerations, public perception, etc.

Please select one of the categories of acceptability (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.

**Rationale:**
The implementation of awareness campaigns is generally well accepted.

**Additional cost information**
When not already included above, or in the species Risk Assessment.
- implementation cost for Member States
- the cost of inaction
- the cost-effectiveness
- the socio-economic aspects

Include quantitative &/or qualitative data, and case studies (incl. from countries outside the EU).

The cost of inaction should be greater than the cost of implementing prevention methods, due to the difficulty of eradication of this species once established.

**Level of confidence on the information provided**
Please select one of the confidence categories along with a statement to support the category chosen. See Notes section at the bottom of this document.

**Rationale:**
Public awareness campaigns have been run in a number of countries, including within the EU, and are important tools to stop human-mediated spread of invasive aquatic plants, with positive results in the countries in which they have been implemented.
**Surveillance measures to support early detection** - Measures to run an effective surveillance system for achieving an early detection of a new occurrence (cf. Article 16). This section assumes that the species is not currently present in a Member State, or part of a Member State’s territory. This table is repeated for each of the early detection measures identified.

<table>
<thead>
<tr>
<th>Measure description</th>
<th>Citizen science</th>
</tr>
</thead>
</table>
| Provide a description of the measure, and identify its objective | Citizen science can broadly be defined as the involvement of volunteers in science, and it is often done in collaboration with a coordinating national body (e.g. Maistrello et al., 2016). Over the past decade there has been a rapid increase in the number of citizen science initiatives and the breadth of environmental-based citizen science is immense. 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).

EU Regulation 1143/2014 acknowledges the importance of citizens in contributing to the successful implementation of EU policy on invasive alien species. The general public’s contribution is facilitated through the European Alien Species Information Network’s (EASIN) ‘Alien Species in Europe’ app, which enables pictures of invasive alien species of Union concern to be recorded, together with complementary information about their observations. The IASTracker app is another application that allows to report possible occurrences of invasive alien species around the world, using a pre-defined list of some well-known invasive species.

A problem with using citizen science for *Myriophyllum* spp. is the difficulty in determining the exact species accurately, because of the high phenotypic plasticity and the high number of the species within the genus *Myriophyllum*.

<table>
<thead>
<tr>
<th>Scale of application</th>
<th>At nationwide level.</th>
</tr>
</thead>
<tbody>
<tr>
<td>At what scale is the measure applied? What is the largest scale at which it has been successfully used? Please provide examples, with areas (km² or ha) if possible.</td>
<td>At nationwide level.</td>
</tr>
</tbody>
</table>
Effectiveness of the measure
Is it effective in relation to its objective? Has the measure previously worked, failed?

Please select one of the categories of effectiveness (with an 'X'), and provide a rationale, with supporting evidence and examples if possible.

<table>
<thead>
<tr>
<th>Effectiveness of</th>
<th>Effective</th>
<th>X</th>
<th>Neutral</th>
<th>Ineffective</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>measures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Rationale:
Delaney et al. (2008) successfully used the data collected by citizen scientists to create a large-scale standardised 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 Myriophyllum spp., this percentage is likely to be lower, except during the flowering period.

Effort required
e.g. period of time over which measure needs to be applied to have results

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”.

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

Roy et al. (2012) state that the use of volunteers in citizen science is critical for its success and, at a European-level, is supported through SEBI’s (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 and 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 on biodiversity datasets developed by volunteer naturalists (Levrel et al., 2010). The participation of volunteers in the development of these monitoring schemes is not only beneficial for collating large-scale and long-term datasets, but also results in other advantages, including improvement of the public’s knowledge of biodiversity (Cooper et al., 2007), support of public debates and reduction in the costs of biodiversity monitoring (Levrel et al., 2010).

Integration of accurate citizen science requires a coordinating scientific or government body. Normally the work would be funded by research grant funds, or through direct funding of scientific organisations by MS governments. Annual costs of running citizen science projects in the UK in 2007-2008 were estimated at between €80,000 and €170,000 (Roy et al., 2012).

Side effects (incl. potential) – both positive and negative
i.e. positive or negative side effects of the measure on public health,

<table>
<thead>
<tr>
<th>Environmental effects</th>
<th>Positive</th>
<th>X</th>
<th>Neutral or mixed</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social effects</td>
<td>Positive</td>
<td>X</td>
<td>Neutral or mixed</td>
<td>Negative</td>
</tr>
<tr>
<td>Economic effects</td>
<td>Positive</td>
<td>X</td>
<td>Neutral or mixed</td>
<td>Negative</td>
</tr>
</tbody>
</table>

¹ Including costs of any additional support, such as volunteer coordination or training.
Environment including non-targeted species, etc.

For each of the side effect types please select one of the impact categories (with an 'X'), and provide a rationale, with supporting evidence and examples if possible.

<table>
<thead>
<tr>
<th>Acceptability to stakeholders</th>
<th>Acceptable</th>
<th>X</th>
<th>Neutral or mixed</th>
<th>Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rationale:</strong></td>
<td>Positive side effects include greater awareness of and involvement in environmental problems by the public and trade bodies. The active involvement of volunteers is also likely to provide feedback on potential new non-native species.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Rationale:

Acceptability to stakeholders
- e.g. impacted economic activities, animal welfare considerations, public perception, etc.

Please select one of the categories of acceptability (with an 'X'), and provide a rationale, with supporting evidence and examples if possible.

<table>
<thead>
<tr>
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<th>Neutral or mixed</th>
<th>Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rationale:</strong></td>
<td>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.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Additional cost information

When not already included above, or in the species Risk Assessment.
- implementation cost for Member States
- the cost of inaction
- the cost-effectiveness
- the socio-economic aspects

Include quantitative &/or qualitative data, and case studies (incl. from countries outside the EU).

<table>
<thead>
<tr>
<th>Level of confidence on the information provided</th>
<th>Inconclusive</th>
<th>Unresolved</th>
<th>Established but incomplete</th>
<th>Well established</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rationale:</strong></td>
<td>There is a very large cost benefit ratio for citizen science, which effectively leverages scientific effort. Volunteer observers for biodiversity surveillance in the UK were estimated to contribute time in-kind worth more than £20 million during 2007-08 (<a href="http://www.jncc.gov.uk/page-3721">http://www.jncc.gov.uk/page-3721</a>).</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Rationale:

Level of confidence on the information provided
- Please select one of the confidence categories along with a statement to support the category chosen. See Notes section at the bottom of this document.

<table>
<thead>
<tr>
<th>Level of confidence on the information provided</th>
<th>Inconclusive</th>
<th>Unresolved</th>
<th>Established but incomplete</th>
<th>Well established</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rationale:</strong></td>
<td>Citizen science has been largely used and has been shown to provide significant leverage in observation power and accurate data (depending on experience and training in taxonomic identification) to support early detection of alien species.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Rapid eradication for new introductions** - Measures to achieve eradication at an early stage of invasion, after an early detection of a new occurrence (cf. Article 17). This section assumes that the species is not currently present in a Member State, or part of a Member State’s territory. This table is repeated for each of the eradication measures identified.

<table>
<thead>
<tr>
<th>Measure description</th>
<th>Manual harvesting (hand-pulling) combined with high-pressure water jet</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Provide a description of the measure, and identify its objective</strong></td>
<td>The control of low-density patches of aquatic plants may be successful through hand-pulling (Washington State Noxious Weed Control Board, 2007; Wersal &amp; Madsen, 2007a; Bailey et al., 2008; EUPHRESCO DeCLAIM, 2011; Q-Bank, 2011; Delbart et al., 2012; Plantlife, 2019). This measure has been used for the management of <em>Myriophyllum</em> species (Hussner et al., 2017). However, great care should be taken with such methods, as they cause fragmentation of the plant, therefore increasing potential spread (EPPO, 2016).</td>
</tr>
<tr>
<td></td>
<td>A rapid integrated management measure is the combination of hand removal with the application of a high-pressure water jet. In a shallow (&lt;1 m) pond system in Düsseldorf (Germany), hand-pulling was combined with hand application of the Hydro Venturi System. The Hydro Venturi System works by using a high-pressure jet of water to uproot the plants, which can then be removed from the water surface (Hussner et al., 2017). Another option is the combination of manual removal, raking and hydro venture, which has been tested in small pond systems (about 1 ha) in North Rhine-Westphalia (A. Hussner, pers. comm.). The Hydro Venturi has also been successfully used for the reduction of biomass and abundance of <em>Cabomba caroliniana</em> and <em>M. heterophyllum</em> in a shallow lake in the Netherlands (van Valkenburg, 2011).</td>
</tr>
<tr>
<td><strong>Scale of application</strong></td>
<td>Hand pulling and harvesting may offer temporary control of small infestations of less than 0.4 hectares (Wersal &amp; Madsen, 2007a). The eradication of extensive infestations in large open waters using this method would not be feasible (Millane &amp; Caffrey, 2014).</td>
</tr>
</tbody>
</table>
Effectiveness of the measure
Is it effective in relation to its objective? Has the measure previously worked, failed?

Please select one of the categories of effectiveness (with an 'X'), and provide a rationale, with supporting evidence and examples if possible.

<table>
<thead>
<tr>
<th>Effectiveness of measures</th>
<th>Effective</th>
<th>X</th>
<th>Neutral</th>
<th>Ineffective</th>
<th>Unknown</th>
</tr>
</thead>
</table>

Rationale:
Hand pulling in small areas can be effective if the entire plant is removed, but only temporary control is achieved (Guillarmod, 1977; Wersal & Madsen, 2007a; EUPHRESCO DeCLAIM, 2011). Eradication may only be feasible in the initial stages of infestation (Delbart et al., 2012). Hand removal is more cost-effective and more efficient in areas with small, high-density *Myriophyllum* infestations (Bailey et al., 2008).

*M. heterophyllum* stems are brittle and, even in soft sediments, a combination with prior use of the Hydro Venturi system works better than when other mechanical control measures, such as weed cutting, are used (van Valkenburg, 2011; Hussner et al., 2017). A single treatment with a modified hand application of the Hydro Venturi system, in combination with hand removal of the uprooted plants, reduced biomass and abundance of *M. heterophyllum* by >99% (controlled one year after the management) in a shallow channel system in Düsseldorf (A. Hussner, pers. comm.). The combination of manual removal, raking and hydro venture reduced the plant biomass/volume of *M. aquaticum* from 45 m³ to 20 l, indicating a high level of control by this integrated control programme (A. Hussner, pers. comm.).

Effort required
e.g. period of time over which measure needs to be applied to have results

In small infestations, manual removal is relatively easily achieved depending on the sediment. Care must be taken to remove all plant parts (emergent shoots, submersed shoots, and roots), as well as fragments created by the removal, or re-growth will occur (Wersal et al., 2015). As it is very likely that regrowth from fragments will occur, despite careful biosecurity arrangements, additional monitoring of the managed site will be required on a regular basis after removal. The plants will need to be removed once, or several times, during the first years after eradication (Delbart et al., 2012). It is recommended that this is done at least every six to nine weeks, from March to October (Environment Agency, 2010). The infestation should be isolated by dams or weighted nets can be used, depending on site specifics (EUPHRESCO DeCLAIM, 2011).

Resources required
E.g. cost, staff, equipment etc.

Hand harvesting is labour-intensive and time-consuming (EUPHRESCO DeCLAIM, 2011), as dense mats are heavy and difficult to haul out of the water (Guillarmod, 1977). The removal of the species from areas of less than 100 m² should take about one day, with the involvement of at least three people. The cost estimate for hand pulling is 875 € per 100 m² (Delbart et al., 2012).
Costs of the Hydro Venturi system, when taking into account all preparatory work and aftercare, can be around 1.35-2.05 € per m² (EPPO, 2015), but the exact cost will depend on the extent of the affected area, type of sediment and other variables (van Valkenburg et al., 2011).

<table>
<thead>
<tr>
<th>Side effects (incl. potential) – both positive and negative</th>
<th>Environmental effects</th>
<th>Positive</th>
<th>Neutral or mixed</th>
<th>X</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>i.e. positive or negative side effects of the measure on public health, environment including non-targeted species, etc.</td>
<td>Social effects</td>
<td>Positive</td>
<td>Neutral or mixed</td>
<td>X</td>
<td>Negative</td>
</tr>
<tr>
<td>For each of the side effect types please select one of the impact categories (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.</td>
<td>Economic effects</td>
<td>Positive</td>
<td>Neutral or mixed</td>
<td>X</td>
<td>Negative</td>
</tr>
</tbody>
</table>

**Rationale:**
Hand-pulling control is mostly selective and therefore non-target plants will not be damaged. The Hydro Venturi system is not species-specific, but the effects on other native aquatic plants are reduced when hand-application is used by a skilled operator.

<table>
<thead>
<tr>
<th>Acceptability to stakeholders</th>
<th>Acceptability to stakeholders</th>
<th>Acceptable</th>
<th>X</th>
<th>Neutral or mixed</th>
<th>Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>e.g. impacted economic activities, animal welfare considerations, public perception, etc.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Please select one of the categories of acceptability (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Rationale:**
Hand-pulling is generally accepted by stakeholders. Issues that tend to cause problems are the disposal of waste, especially when piles of rotting material are left in the site.

**Additional cost information**¹
- implementation cost for Member States
- the cost of inaction
- the cost-effectiveness
- the socio-economic aspects

Include quantitative &/or qualitative data, and case studies (incl. from countries outside the EU).

Given the high costs of long-term management measures for these species, a prompt response to newly establishing populations is important to avoid that.
**Level of confidence on the information provided**

Please select one of the confidence categories along with a statement to support the category chosen. See Notes section at the bottom of this document.

**NOTE** – this is not related to the effectiveness of the measure

<table>
<thead>
<tr>
<th>Inconclusive</th>
<th>Unresolved</th>
<th>Established but incomplete</th>
<th>X</th>
<th>Well established</th>
</tr>
</thead>
</table>

**Rationale:**
The combination of the Hydro Venturi system with hand removal has been shown to be effective, but further research is needed.

---

**Management** - Measures to achieve management of the species once it has become widely spread within a Member State, or part of a Member State’s territory. (cf. Article 19), i.e. not at an early stage of invasion (see Rapid eradication table above). These measures can be aimed at eradication, population control or containment of a population of the species. **This table is repeated for each of the management measures identified.**

### Measure description
Provide a description of the measure, and identify its objective

<table>
<thead>
<tr>
<th>Mechanical control</th>
</tr>
</thead>
</table>

Mechanical harvesting, cutting, raking, chaining (long chains of sharp blades) and rotovation (underwater rototilling) that remove the root of the species could provide control. However, mechanical harvesting that simply cuts the plants only serves to fragment the species and potentially extend its range of distribution (Wersal et al., 2011). Fragments are specially adapted for propagation, as they are capable of floating in the water column for weeks before rooting (Xie et al., 2010), and both rhizomes and stem fragments have extremely high survival rates (Xie et al., 2010, 2013), which could increase species spread (EUPHRESCO DeCLAIM, 2011; Q-Bank, 2011; GISD, 2015).

### Scale of application
At what scale is the measure applied? What is the largest scale at which it has been successfully used? Please provide examples, with areas (km² or ha) if possible.

In general, mechanical control measures are very time- and cost-intensive and rarely successful, apart from at small scales (Hussner & Champion, 2011).
### Effectiveness of the measure

Is it effective in relation to its objective? Has the measure previously worked, failed?

Please select one of the categories of effectiveness (with an 'X'), and provide a rationale, with supporting evidence and examples if possible.

<table>
<thead>
<tr>
<th>Effectiveness of measures</th>
<th>Effective</th>
<th>Neutral</th>
<th>Ineffective</th>
<th>X</th>
<th>Unknown</th>
</tr>
</thead>
</table>

**Rationale:**

As *M. aquaticum* regrows rapidly from shoot fragments, mechanical cutting is rarely effective (Guillarmod, 1977), with the species becoming dominant again in two months (Ferreira & Moreira, 1990a). Raking may not be feasible due to the rapid biomass production of this species and has low effectiveness (Wersal & Madsen, 2007a), and repeat cutting favours the dominance of the species (Wersal et al., 2011). Mechanical removal lasts for a short to medium-term and cutting does not have a long-term effect (Q-Bank, 2011). Mechanical harvesting can, however, be effective for small areas (Wersal & Madsen, 2007a).

Dense stands of *M. heterophyllum*, up to 190 tonnes of fresh weight, occurring in shallow lakes in Germany, have been regularly cut for over 10 years in summer, using a weed-cutting boat. There has been a remarkable reduction of the biomass and abundance of the species, but without any long-term effect (Hussner et al., 2005; Hussner & Krause, 2007; A. Hussner, pers. comm.). An experiment performed in Maine (USA) found mechanical cutting to be impractical, with removal by hand and benthic mats being more effective management measures (Bailey et al., 2008).

### Effort required

e.g. period of time over which measure needs to be applied to have results

Mechanical control options may be better practised during the winter, when plants are less active and regrowth is less likely. The most effective maintenance using this measure occurs when water bodies are harvested in early summer, combined with dredging (Moreira et al., 1999).

### Resources required

e.g. cost, staff, equipment etc.

Control of *Myriophyllum* spp. can be very costly. In the western USA, it costs over $50,000 a year to remove *Myriophyllum* species from drainage ditches by mechanical methods (Anderson, 1993). The cost estimate for mechanical pulling is 92.5 € per 100 m² (Delbart et al., 2012) and the cost of removal using a weed-cutting boat is 45,000 € for more than one lake (Hussner & Krause, 2007).

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, which entails more costs. Additional costs should also be considered in order to remove from the water the fragments generated by the cutting, in order to prevent regrowth (Q-Bank, 2011; Plantlife, 2019) and it is recommended that nets be put in place before any mechanical removal commences (EUPHRESCO DeCLAIM, 2011).

### Side effects (incl. potential) – both positive and negative

<table>
<thead>
<tr>
<th>Environmental effects</th>
<th>Positive</th>
<th>Neutral or mixed</th>
<th>Negative</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social effects</td>
<td>Positive</td>
<td>Neutral or mixed</td>
<td>X</td>
<td>Negative</td>
</tr>
</tbody>
</table>
i.e. positive or negative side effects of the measure on public health, environment including non-targeted species, etc.

For each of the side effect types please select one of the impact categories (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.

<table>
<thead>
<tr>
<th>Economic effects</th>
<th>Positive</th>
<th>Neutral or mixed</th>
<th>X</th>
<th>Negative</th>
</tr>
</thead>
</table>

Rationale:
As mechanical control, such as cutting, is non-specific, some impacts must be expected in the native biota, especially related to native aquatic plants. Mechanical control can damage surrounding areas and non-target plants can be affected. Nevertheless, environmental impact is limited when the infestation is small.

Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc.

Please select one of the categories of acceptability (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.

<table>
<thead>
<tr>
<th>Acceptability to stakeholders</th>
<th>Acceptable</th>
<th>X</th>
<th>Neutral or mixed</th>
<th>Unacceptable</th>
</tr>
</thead>
</table>

Rationale:
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
When not already included above, or in the species Risk Assessment.
- implementation cost for Member States
- the cost of inaction
- the cost-effectiveness
- the socio-economic aspects

Include quantitative &/or qualitative data, and case studies (incl. from countries outside the EU).

The cost of inaction will be very high and total eradication after extensive establishment is unlikely.

Level of confidence on the information provided
Please select one of the confidence categories along with a statement to support the category chosen. See

<table>
<thead>
<tr>
<th>Inconclusive</th>
<th>Unresolved</th>
<th>Established but incomplete</th>
<th>X</th>
<th>Well established</th>
</tr>
</thead>
</table>

Rationale:
More research should be undertaken on mechanical control of *Myriophyllum* species, in order to test and improve the effectiveness of these measures.
**Management** - Measures to achieve management of the species once it has become widely spread within a Member State, or part of a Member State’s territory. (cf. Article 19), i.e. **not** at an early stage of invasion (see Rapid eradication table above). These measures can be aimed at eradication, population control or containment of a population of the species. **This table is repeated for each of the management measures identified.**

<table>
<thead>
<tr>
<th>Measure description</th>
<th>Environmental control</th>
</tr>
</thead>
</table>
| Provide a description of the measure, and identify its objective | Lightproof barriers:  
Covering the plants with lightproof barriers such as plastic foils, tarpaulins, planting trees in the south-facing banks or shores, or using dye in order to reduce the photosynthetic capacity of the plants can control growth and eventually eradicate the plants. Lightproof barriers have been used with some success to control *M. heterophyllum* and *M. spicatum* (Laitala et al., 2012; Hussner et al., 2017). However, *M. aquaticum* is adapted to a wide variety of conditions, from full sun to partial shade (Smith, 2008) and its growth form is adapted to shady environments (Wersal & Madsen, 2011; Xie et al., 2013). Nevertheless, the drastic and prolonged reduction of light could reduce the growth of new stalks of *M. aquaticum*, as shading (e.g., by riparian trees) may be a major limiting environmental factor for this species (Sytsma & Anderson, 1993a; Tan et al., 2019).  

Water level drawdown:  
Water level drawdown consists of a deliberate lowering of the water level of a water body to expose the plants to drying conditions. While *M. aquaticum* may be able to survive drawdown periods of up to nine months, as long as the sediment remains saturated (Wersal & Madsen, 2011), and shows an ability to respond to drained soil conditions by a rapid root growth (Hussner et al., 2009), the rhizomes are no longer viable following 80% mass loss (Barnes et al., 2013). This control method has been proposed by EPPO (2015) for *M. heterophyllum*, but it has not been assessed.  

Reducing nutrients:  
As *M. aquaticum* is associated with eutrophic waters (Tan et al., 2019), a reduction in nutrient loading by buffer strips and control of sewage works and farm effluents to reduce nutrients (CEH, 2004), may offer control possibilities (Sytsma & Anderson, 1993a). |
**Scale of application**
At what scale is the measure applied? What is the largest scale at which it has been successfully used? Please provide examples, with areas (km² or ha) if possible.

Lightproof barriers may be used in small areas (swimming beaches, boating lanes, around docks), but they are not effective for large infestations (Bailey & Calhoun, 2008). Water level drawdown is feasible for long term drying-out of small ponds. No information is available about the scale of application needed in order to reduce nutrients with some effect on *Myriophyllum* spp.

**Effectiveness of the measure**
Is it effective in relation to its objective? Has the measure previously worked, failed?

Please select one of the categories of effectiveness (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.

<table>
<thead>
<tr>
<th>Effectiveness of measures</th>
<th>Effective</th>
<th>Neutral</th>
<th>Ineffective</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Rationale:**
Lightproof barriers are an appropriate option for controlling thick, extensive cover of *M. heterophyllum* and, along with hand-removal methods, are the most effective management technique (Bailey et al., 2008). However, *M. aquaticum* prefers high light intensity (Hussner, 2009) and survives in 70% shade, with the lowest growth having been reported at 60% shading (Wersal & Madsen, 2013; Tan et al., 2019). As such, lightproof barriers will be effective for *M. heterophyllum* and submerged *M. aquaticum*, but probably not practical for emergent *M. aquaticum* (A. Hussner, pers. comm.).

To be successful, a drawdown would have to be sustained long enough to dry the soil completely, as *M. aquaticum* can and will survive in moist soils (Wersal et al., 2015) and in drained sediments (Hussner et al., 2009). The survival of the plants following simulated drawdown events was found to be higher in winter (78%) than in summer (18%) (Wersal et al., 2013). This management technique is not particularly effective for the control of *M. aquaticum*.

The mean plant height and the number of roots of *M. aquaticum* responded significantly to a reduction in nutrient levels (Tan et al., 2019). Therefore, the reduction of nutrients will be effective in managing this species.

**Effort required**
e.g. period of time over which measure needs to be applied to have results

Regarding the use of lightproof barriers, during spring and winter, the best option is using opaque, floating material or dyes for 3-4 months (Q-Bank, 2011; PIER, 2017). Increasing shade by any control mechanism in early spring should be maintained for at least a year to have some effect (CEH, 2004).

For water level drawdown, a complete dry-out of the ponds should be done for a minimum period of 9 months (Wersal & Madsen, 2011); in an experimental study, biomass of *M. aquaticum* was reduced after 12 weeks of dry out (Wersal et al., 2013).
The cost of lightproof barriers is estimated at about $30,000 per ha, excluding any removal of sediments (De Winton et al., 2013). Although barrier installation requires less time to implement than other alternative methods, its costs are roughly triple the costs of hand removal and mechanical cutting (Bailey et al., 2008). Independently of its high cost per area, the cost-effectiveness of using this measure is high for small infestations.

A drawdown in water level is not highly costly, but can only be carried out in water bodies in which the water level can be actively manipulated, with reservoirs being the most difficult to implement.

<table>
<thead>
<tr>
<th>Side effects (incl. potential) – both positive and negative</th>
<th>Environmental effects</th>
<th>Social effects</th>
<th>Economic effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>i.e. positive or negative side effects of the measure on public health, environment including non-targeted species, etc.</td>
<td>Positive</td>
<td>Neutral or mixed</td>
<td>Negative X</td>
</tr>
<tr>
<td>For each of the side effect types please select one of the impact categories (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.</td>
<td></td>
<td>Neutral or mixed</td>
<td>X Negative</td>
</tr>
</tbody>
</table>

**Rationale:**
Lightproof barriers are non-selective methods that can have a negative impact on benthic organisms and need to be properly maintained; as such, they should be reserved for areas of heavy monocultural infestations of *Myriophyllum* species (EPPO, 2009; EUPHRESCO DeCLAIM, 2011). For example, undesirable side effects of dye have been reported following the use of dyes to control problematic epiphytes, leading to healthier and larger *Myriophyllum* plants (Hussner et al., 2017).

Both lightproof barriers and water level drawdown may affect the native fauna and flora community of the invaded water body. Water level drawdowns might affect the human use of water bodies.

<table>
<thead>
<tr>
<th>Acceptability to stakeholders</th>
<th>Acceptability to stakeholders</th>
<th>Acceptable</th>
<th>Neutral or mixed</th>
<th>X</th>
<th>Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>e.g. impacted economic activities, animal welfare considerations, public perception, etc.</td>
<td></td>
<td>Acceptable</td>
<td>Neutral or mixed</td>
<td>X</td>
<td>Unacceptable</td>
</tr>
</tbody>
</table>

**Rationale:**
Lightproof barriers do not have a negative impact on economic activities, although covering plants with materials such as plastic foils might not be well accepted by the general public.

Water level drawdowns might also not be well accepted, as they may affect the human use of water bodies.

<table>
<thead>
<tr>
<th>Additional cost information ¹</th>
<th>No information available.</th>
</tr>
</thead>
<tbody>
<tr>
<td>When not already included above, or in the species Risk Assessment.</td>
<td>- implementation cost for Member States</td>
</tr>
</tbody>
</table>
- the cost of inaction
- the cost-effectiveness
- the socio-economic aspects

Include quantitative &/or qualitative data, and case studies (incl. from countries outside the EU).

<table>
<thead>
<tr>
<th>Level of confidence on the information provided</th>
<th>Inconclusive</th>
<th>Unresolved</th>
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<th>Well established</th>
</tr>
</thead>
<tbody>
<tr>
<td>Please select one of the confidence categories along with a statement to support the category chosen. See Notes section at the bottom of this document.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE – this is not related to the effectiveness of the measure

Rationale:
There is clear, established evidence that lightproof barriers and water level drawdown could be used as control of *M. aquaticum*, but more research is needed for *M. heterophyllum*, and also on the method of reducing nutrients.

Management - Measures to achieve management of the species once it has become widely spread within a Member State, or part of a Member State’s territory. (cf. Article 19), i.e. not at an early stage of invasion (see Rapid eradication table above). These measures can be aimed at eradication, population control or containment of a population of the species. This table is repeated for each of the management measures identified.

<table>
<thead>
<tr>
<th>Measure description</th>
<th>Chemical control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide a description of the measure, and identify its objective</td>
<td></td>
</tr>
<tr>
<td>(Note that EU legislation on the use of plant protection products and biocides must be respected and none of the active ingredients mentioned below are currently approved for use in or near water in the EU.)</td>
<td></td>
</tr>
<tr>
<td>Herbicide control is recommended in some states of the USA for the management of <em>M. heterophyllum</em> (Getsinger et al., 2003). Triclopyr is effective against <em>M. heterophyllum</em> over a wide range of concentrations and exposure times in the field (Getsinger et al., 2003). Glomski &amp; Netherland (2008) found that diquat provided good control of <em>M. heterophyllum</em> and exposure to carfentrazone significantly reduced its biomass. Fluridone and penoxsulam are also reported to control <em>M. heterophyllum</em> (Glomski &amp; Netherland, 2008).</td>
<td></td>
</tr>
<tr>
<td>Herbicides have also been used for control of <em>M. aquaticum</em> (e.g. Moreira et al., 1999). In mesocosms, total efficacy was achieved by application of 2,4-D, imazapyr or triclopyr (Negrisoli et al., 2003; Hofstra et al., 2006; Wersal &amp;</td>
<td></td>
</tr>
</tbody>
</table>
In a field study, the effectiveness of three chemical treatments to control this species (imazapyr, imazapyr + carfentrazone and 2,4-D + carfentrazone) was tested in four locations along the Chehalis River, Washington State, USA (Kuehne et al., 2018). Furthermore, the use of 2,4-D and triclopyr as foliar applications has resulted in consistent control of *M. aquaticum* (Hofstra et al., 2006). In Portugal, the use of 2,4-D amine, glyphosate-ammonium and glyphosate has been tested (Ferreira & Moreira, 1990b).

### Scale of application

At what scale is the measure applied? What is the largest scale at which it has been successfully used? Please provide examples, with areas (km² or ha) if possible.

Herbicides should be applied in the specific area where the plant is located. The literature does not mention the area over which chemical control has been successful.

### Effectiveness of the measure

Is it effective in relation to its objective? Has the measure previously worked, failed? Please select one of the categories of effectiveness (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.

<table>
<thead>
<tr>
<th>Effectiveness of measures</th>
<th>Effective</th>
<th>Neutral</th>
<th>Ineffective</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rationale:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bispyribac-sodium had no effect on <em>M. heterophyllum</em>, but diquat provided good control of the species (85% reduction), fluridone and penoxsulam reduced biomass by over 80% (Glomski &amp; Netherland, 2008) and 2,4-D reduced coverage by up to 100% (Haug &amp; Bellaud, 2013).</td>
<td><strong>X</strong></td>
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</table>

For control of *M. aquaticum* in mesocosms: fluridone and clopyralid were not effective (Hofstra et al., 2006; Wersal & Madsen, 2007b); glyphosate, endothall, dichlobenil and imazapyr reduced biomass by more than 90% (Hofstra et al., 2006; Emerine et al., 2010); imazamox in high concentrations reduced biomass by 80% (Emerine et al., 2010); 2,4-D resulted in 90% biomass reduction (Wersal & Madsen, 2010); and complete eradication was achieved with triclopyr (Hofstra et al., 2006).

Regrowth occurred in a mesocosms experiment, regardless of the herbicide or treatment method used, indicating that multiple applications would be necessary to provide long term control (Wersal & Madsen, 2010). In another experiment, 2,4-D by itself was 100% effective at controlling *M. aquaticum*, with a low chance of the species recovering (Gray et al., 2007). Based on the results of Wersal & Madsen (2007b), imazapyr was effective as a foliar application for the control of *M. aquaticum*, as there was complete control of the plant after 10 weeks, with no regrowth.

In the field, after six weeks of treatment with 2,4-D + carfentrazone, *M. aquaticum* biomass was reduced by 23%, with regrowth accounted for (Kuehne et al., 2018). When carfentrazone-ethyl was combined with 2,4-D, it resulted in excellent control of small *M. aquaticum* populations (Gray et al., 2007). In Portugal, the application of 2,4-D...
showed a highly significant biomass reduction, but regrowth occurred after two months of treatment (Ferreira & Moreira, 1990b).

| Effort required | The effectiveness of herbicide applications will be site-specific and depend upon the environmental conditions at the time of application (Wersal et al., 2015); quite often, multiple applications are necessary. The optimum time for applying chemical control is likely to be the start of the growing season of *Myriophyllum* plants, from April onwards (CEH, 2004; EUPHRESCO DeCLAIM, 2011). |
| Resources required | The cost estimate for application of chemical control is 21 € per 100 m² (Delbart et al., 2012). Some difficulty is anticipated when using herbicides to treat weeds in water (requiring the use of small boats), and the cost of education and training of local stakeholders should be included as part of the treatment programme. |
| Side effects (incl. potential) – both positive and negative | Environmental effects | Positive | Neutral or mixed | Negative | X |
| | Social effects | Positive | Neutral or mixed | X | Negative |
| | Economic effects | Positive | Neutral or mixed | X | Negative |
| Rationale: | Herbicides are non-specific; therefore, it must be assumed that this method of control has a negative impact on freshwater biota. |

| Acceptability to stakeholders | Acceptability to stakeholders | Acceptable | Neutral or mixed | Unacceptable | X |
| | Rationale: | | | | |

Acceptability to stakeholders e.g. impacted economic activities, animal welfare considerations, public perception, etc. |
Please select one of the categories of acceptability (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.

| None of the active ingredients of the chemical components mentioned above is currently approved for use in, or near, water in the EU. Acceptability by stakeholders must be considered negligible. |

**Additional cost information**

When not already included above, or in the species Risk Assessment.
- implementation cost for Member States
- the cost of inaction
- the cost-effectiveness
- the socio-economic aspects

Include quantitative &/or qualitative data, and case studies (incl. from countries outside the EU).

The cost of implementation for MS will be linked to the cost of surveying and monitoring, which are dependent on the effort applied.

<table>
<thead>
<tr>
<th>Level of confidence on the information provided</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inconclusive</td>
</tr>
</tbody>
</table>

**Rationale:**
The use of herbicides to control aquatic plants has a long record of research undertaken on the effectiveness of different active ingredients and its application, but more field research is needed for *Myriophyllum* species.

**Management**

Measures to achieve management of the species once it has become widely spread within a Member State, or part of a Member State’s territory. (cf. Article 19), i.e. not at an early stage of invasion (see Rapid eradication table above). These measures can be aimed at eradication, population control or containment of a population of the species. This table is repeated for each of the management measures identified.

<table>
<thead>
<tr>
<th>Measure description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide a description of the measure, and identify its objective</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Integrated management plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple integrated measures may be needed, and have been proposed, for the control of <em>Myriophyllum</em> species.</td>
</tr>
</tbody>
</table>
**Integrated mechanical with chemical control:**
The effectiveness of chemical control increases if mechanical harvesting precedes chemical treatment, when plant cover is higher than 50% (Moreira et al., 1999; Q-Bank, 2011). This can be done by removing plants during winter, and then following up by spraying any regrowth in early spring (PIER, 2017).

**Integrated manual, environmental and chemical control:**
This can be done through a combination of a short dry-out period with the application of chemical treatment, and complementary careful yearly hand-pulling; this measure should be extended over two years (Delbart et al., 2012).

**Integrated environmental with mechanical control:**
This can consist in lowering the water level, or dry-out, for two-three weeks, and removing plants mechanically afterwards (PIER, 2017).

Harvesting plus dredging of *Myriophyllum* in early summer is effective for a year (Ferreira & Moreira, 1990a). If the water level is kept high during the summer season, and if floods keep channels clean in winter, this method could be effective for the following two years (but no further quantitative information about their effects is available). This is applicable only for medium-big channels with water depths >0.5 m and with flooding in winter (Moreira et al., 1999).

<table>
<thead>
<tr>
<th>Scale of application</th>
<th>None known.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effect of measures</td>
<td>Effective X</td>
</tr>
</tbody>
</table>

**Rationale:**
As mentioned in the examples above (see section ‘Measure description’), most of these combined measures seem to be relatively effective in controlling *Myriophyllum*.

**Effort required**
As mentioned in the examples above (see section ‘Measure description’), each of the combined measures needs to be applied for different periods of time.
In Ireland, the estimated cost of eradicating a *M. aquaticum* population from a single lake using a combination of mechanical, herbicidal and environmental control methods was £50,000 - £100,000 (Kelly & Maguire, 2009). Costs relating to manual post-mechanical and post-chemical finishing have been considered by other authors and amount, respectively, to 45 and 400 € per m² (Delbart et al., 2012).

### Side effects (incl. potential) – both positive and negative
i.e. positive or negative side effects of the measure on public health, environment including non-targeted species, etc.

For each of the side effect types please select one of the impact categories (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.

| Environmental effects | Positive | Neutral or mixed | Negative | X |
|-----------------------|----------|------------------|----------|
| Social effects        | Positive | Neutral or mixed | X        | Negative |
| Economic effects      | Positive | Neutral or mixed | X        | Negative |

**Rationale:**
Physical removal (manual harvesting), drying-out, shading and herbicide treatments are mostly non-specific means of control. As such, either one of these actions will inevitably have effects on local flora and fauna, or cause habitat disturbance.

### Acceptability to stakeholders
e.g. impacted economic activities, animal welfare considerations, public perception, etc.

Please select one of the categories of acceptability (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.

<table>
<thead>
<tr>
<th>Acceptability to stakeholders</th>
<th>Acceptable</th>
<th>Neutral or mixed</th>
<th>X</th>
<th>Unacceptable</th>
</tr>
</thead>
</table>

**Rationale:**
Mechanical control of aquatic plants is generally accepted by stakeholders. Lightproof barriers do not have a negative impact on economic activities, whereas water-level drawdowns might affect the human use of water bodies. Chemical control is not currently approved for use in or near water in the EU.
Include quantitative &/or qualitative data, and case studies (incl. from countries outside the EU).

<table>
<thead>
<tr>
<th>Level of confidence on the information provided</th>
<th>Inconclusive</th>
<th>Unresolved</th>
<th>Established but incomplete</th>
<th>X</th>
<th>Well established</th>
</tr>
</thead>
</table>

Rationale:
The amount of research undertaken on combining different control methods should be increased.

**Management** - Measures to achieve management of the species once it has become widely spread within a Member State, or part of a Member State’s territory. (cf. Article 19), i.e. not at an early stage of invasion (see Rapid eradication table above). These measures can be aimed at eradication, population control or containment of a population of the species. **This table is repeated for each of the management measures identified.**

<table>
<thead>
<tr>
<th>Measure description</th>
<th>Provide a description of the measure, and identify its objective</th>
</tr>
</thead>
</table>
| **Biological control** | Natural enemies of *M. heterophyllum* in its native range, which have been observed to feed on emergent or submerged leaves, petioles and stems, are: *Donacia cincticornis* (Coleoptera, Chrysomelidae), *Perenthis vestitus* (Coleoptera, Curculionidae), *Mystacoides longicornis*, *Oecetis cinerascens*, *Triaenodes injusta*, *Triaenodes marginata*, *Triaenodes* spp. (Trichoptera, Leptocertidae) (McGaha, 1952). Initial surveys of nematode communities for biocontrol of this species have been conducted in the USA (University of New Hampshire, 2008). The aquatic weevil *Eubrychius velutus* is distributed throughout Europe and Asia; it feeds on the meristem and leaves of diverse species of the genus *Myriophyllum*, including *M. heterophyllum*, and has potential as a biological control agent (Newman et al., 2006). Significant damage of *Eubrychius* sp. to *M. heterophyllum* (particularly to the apices) has been reported (A. Hussner, pers. comm.). However, no specific biological control agents have been identified yet. Several biological control agents have already been found in South America for *M. aquaticum*. The most promising is a leaf-feeding beetle from Argentina, *Lysathia n.sp*. (Coleoptera: Chrysomelidae), which is host-specific to *M. aquaticum* (Cilliers, 1999a). Also, the stem-boring weevil *Listronotus marginicollis* (Coleoptera: Curculionidae) has
been found to show a feeding and host preference for parrot’s feather, often killing its terminal bud (Oberholzer et al., 2007). This is a promising candidate to supplement the damage caused by *Lysathia n.sp.*; however, none seem to be in use.

Several fungi have been tested as potential control agents for *M. aquaticum*, e.g. *Pythium carolinianum* (Bernhardt & Duniway, 1984). Other experimental fungal treatments applied using *Chaetomella raphigera*, *Cercospora* sp. and *Mycosphaerella* sp. from the Neotropics, were seen to have effects on parrot’s feather populations (Barreto et al., 2000). Also, mycoherbicides such as the bacterium *Xanthomonas campestris* in South Africa (Morris et al., 1999) and *Mycoleptodiscus terrestris* have been tested (Verma & Charudattan, 1993). Hussner (2016) reported some damage to *M. aquaticum* in Germany due to a bacterial infection with *Pseudomonas* sp.

Grass carp (*Ctenopharyngodon idella*) stocked by anglers in Dusseldorf (Germany) resulted in a biomass reduction of *M. heterophyllum*, but not in a sustainable control method for the species (EPPO, 2015; A. Hussner, pers. comm.). Grass carp has been used for the biocontrol of *M. aquaticum* with some success (Moreira et al., 1999; Hill & Coetzee, 2017).

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 must be respected, and before any release of an alien species as a biological control agent, an appropriate risk assessment should be performed. In order to implement biological control using grass carp, the experience reported in these guidelines from New Zealand should be followed (http://www.doc.govt.nz/get-involved/apply-for-permits/interacting-with-freshwater-species/options-for-weed-control/grass-carp/).

**Scale of application**

At what scale is the measure applied? What is the largest scale at which it has been successfully used? Please provide examples, with areas (km² or ha) if possible.

None known.
### Effectiveness of the measure

Is it effective in relation to its objective? Has the measure previously worked, failed?

Please select one of the categories of effectiveness (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.

<table>
<thead>
<tr>
<th>Effectiveness of measures</th>
<th>Effective</th>
<th>Neutral</th>
<th>X</th>
<th>Ineffective</th>
<th>Unknown</th>
</tr>
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<tbody>
<tr>
<td><strong>Rationale:</strong></td>
<td></td>
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<tr>
<td><strong>Lysathia n.sp.</strong> (Coleoptera: Chrysomelidae) reduced the cover of <em>M. aquaticum</em> by more than 50% over 3 years (Cilliers, 1999b). However, in general, <em>M. aquaticum</em> plants are able to recover after suffering severe levels of herbivore damage. Using the weevil <em>Listonotus marginicollis</em>, up to 79% of the stem of plants was damaged due to the larvae activity (Cordo &amp; DeLoach, 1982; Oberholzer et al., 2007). The fungi <em>Pythium carolinianum</em> has been found to have some effectiveness at high densities (Bernhardt &amp; Duniway, 1984). Mycoherbicides have been reported to induce some toxicity (Verma &amp; Charudattan, 1993; Morris et al., 1999), but no further quantitative information about their effects is available.</td>
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Field studies in Argentina and the USA found that grass carp reduced the biomass of aquatic plants, including *M. aquaticum*, up to 85% in two months (Armellina et al., 1999). In a reservoir in North Carolina (USA), it was found that high-density stocking of grass carp reduced the biomass of the species up to 90% in the first year, and achieved complete eradication in the second year (Garner et al., 2013). However, an experiment in Portugal found that grass carp did not reduce biomass, or cover, of parrot’s feather (Catarino et al., 1997).

For *M. hererophyllum*, the use of grass carp in Germany did not eradicate the species (EPPO, 2015) and, in the USA, a reduction in cover from 24 to 54% was noted when triploid grass carp were present (Hanlon et al., 2000). The only experiment performed with grass carp reduced the cover of a *M. hererophyllum* stand by half, after six years (Hanlon et al., 2000).

### Effort required

*E.g.* period of time over which measure needs to be applied to have results

For biological control, the initial period of host-specificity testing would take approximately three years, after which, if approved, the agent could be released. Biological control using the Coleoptera *Lysathia n.sp.* required over 3 years to show effectiveness (Cilliers, 1999b). Biological control using grass carp can take from two months up to year (Armellina et al., 1999; Garner et al., 2013).

### Resources required

*E.g.* cost, staff, equipment etc.

Usually significant effort, and associated resources and costs, are required before and during the release of a biological control agent.

### Side effects (incl. potential) – both positive and negative

*i.e.* positive or negative side effects of the measure on public health,

<table>
<thead>
<tr>
<th>Environmental effects</th>
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<td>Positive</td>
<td>Neutral or mixed</td>
<td>X</td>
<td>Negative</td>
</tr>
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</table>

**Rationale:**


Attempts to control *M. aquaticum* invasions by biological means, e.g. through the introduction of another exotic species, the grass carp, can negatively impact native submerged vegetation and aquatic fauna.

<table>
<thead>
<tr>
<th>Acceptability to stakeholders</th>
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<tbody>
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<td>e.g. impacted economic activities, animal welfare considerations, public perception, etc.</td>
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<tr>
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**Rationale:**
Socio-economic impacts of biological control are rare, and stakeholders are often supportive, if the problem and solution are explained fully. Careful management of biological control programmes is usually necessary, despite the adverse impact of the target weed.

<table>
<thead>
<tr>
<th>Additional cost information ¹</th>
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<tbody>
<tr>
<td>When not already included above, or in the species Risk Assessment.</td>
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<tr>
<td>- implementation cost for Member States</td>
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</table>

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 of 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.

<table>
<thead>
<tr>
<th>Level of confidence on the information provided ²</th>
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<tbody>
<tr>
<td>Please select one of the confidence categories along with a statement to support the category chosen. See Notes section at the bottom of this document.</td>
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<table>
<thead>
<tr>
<th>Inconclusive (Mh)</th>
<th>X</th>
<th>Unresolved</th>
<th>Established but incomplete (Ma)</th>
<th>X</th>
<th>Well established</th>
</tr>
</thead>
</table>

**Rationale:**
Much research is needed to identify the potential natural enemies to be used for biological control of *M. hererophyllum*. For *M. aquaticum*, several studies have been performed, but more quantified evidence of control is needed.
| NOTE – this is not related to the effectiveness of the measure |
### Bibliography

See guidance section.


Heidbüchel, P., Kuntz, K., & Hussner, A. (2016). Alien aquatic plants do not have higher fragmentation rates than native species: a field study from the River Erft. *Aquatic Sciences*, 78(4), 767-777.


Notes

1. Costs information. The assessment of the potential costs shall describe those costs quantitatively and/or qualitatively depending on what information is available. This can include case studies from across the Union or third countries.

2. Level of confidence\(^1\): based on the quantity, quality and level of agreement in the evidence.

   - **Well established**: comprehensive meta-analysis\(^2\) or other synthesis or multiple independent studies that agree.
   - **Established but incomplete**: general agreement although only a limited number of studies exist but no comprehensive synthesis and/or the studies that exist imprecisely address the question.
   - **Unresolved**: multiple independent studies exist but conclusions do not agree.
   - **Inconclusive**: limited evidence, recognising major knowledge gaps

3. Citations and bibliography. The APA formatting style for citing references in the text and in the bibliography is used. e.g. Peer review papers will be written as follows:
   - In text citation: (Author & Author, Year)

(see http://www.waikato.ac.nz/library/study/referencing/styles/apa)

\(^1\) Assessment of confidence methodology is taken from IPBES. 2016. Guide on the production and integration of assessments from and across all scales (IPBES-4-INF-9), which is adapted from Moss and Schneider (2000).

\(^2\) A statistical method for combining results from different studies which aims to identify patterns among study results, sources of disagreement among those results, or other relationships that may come to light in the context of multiple studies.