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Risk analysis of the Variable Watermilfoil *Myriophyllum heterophyllum* Michaux

Risk analysis report of non-native organisms in Belgium

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Adopted in date of : 11 March 2013

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Adopted in date of: 11th March 2013

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This report should be cited as:
Lafontaine, R.-M., Beudels-Jamar, R.C., Delsinne, T., Robert, H. (2013). Risk analysis of the Variable Watermilfoil *Myriophyllum heterophyllum* Michaux. - Risk analysis report of non-native organisms in Belgium from the Royal Belgian Institute of Natural Sciences for the Federal Public Service Health, Food chain safety and Environment. 33 p.

Contents

Acknowledgements

The authors wish to thank the reviewers who contributed to this risk analysis with valuable comments and additional references: Luc Denys (INBO), Mathieu Halford (Université de Liège – Gembloux Agro-Bio Tech.), Arnaud Monty (Université de Liège – Gembloux Agro-Bio Tech.) and Floris Vanderhaeghe (INBO). They also thank Isabelle Bachy (RBINS) who designed the PRA's cover.

Etienne Branquart (Cellule Espèces Invasives, Service Public de Wallonie) developed the risk analysis template that was used for this exercise.

The general process of drafting, reviewing and approval of the risk analysis for selected invasive alien species in Belgium was attended by a steering committee, chaired by the Federal Public Service Health, Food chain safety and Environment. RBINS/KBIN was contracted by the Federal Public Service Health, Food chain safety and Environment to perform PRA's for a batch of species. ULg was contracted by Service Public de Wallonie to perform PRA's for a selection of species. INBO and DEMNA performed risk analysis for a number of species as in-kind contribution.

Steering committee members were:

Tim Adriaens	Research Institute for Nature and Forest (INBO)
Olivier Beck	Brussels Environment (BIM)
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Hans Van Gossum	Agency for Nature and Forest (ANB)
Hugo Verreycken	Research Institute for Nature and Forest (INBO)

Rationale and scope of the Belgian risk analysis scheme

The Convention on Biological Diversity (CBD) emphasises the need for a precautionary approach towards non-native species. It strongly promotes the use of robust and good quality risk assessment to help underpin this approach (COP 6 Decision VI/23). More specifically, when considering trade restrictions for reducing the risk of introduction and spread of a non-native organisms, full and comprehensive risk assessment is required to demonstrate that the proposed measures are adequate and efficient to reduce the risk and that they do not create any disguised barriers to trade. This should be seen in the context of WTO and free trade as a principle in the EU (Baker et al. 2008, Shine et al. 2010, Shrader et al. 2010).

This risk analysis has the specific aim of evaluating whether or not to install trade restrictions for a selection of absent or emerging invasive alien species that may threaten biodiversity in Belgium as a preventive risk management option. It is conducted at the scale of Belgium but results and conclusions could also be relevant for neighbouring areas with similar eco-climatic conditions (e.g. areas included within the Atlantic and the continental biogeographic regions in Europe).

The risk analysis tool that was used here follows a simplified scheme elaborated on the basis of the recommendations provided by the international standard for pest risk analysis for organisms of quarantine concern[1] *produced by the secretariat of the International Plant Protection Convention (FAO 2004). This logical scheme adopted in the plant health domain separates the assessment of entry, establishment, spread and impacts. As proposed in the GB non-native species risk assessment scheme, this IPPC standard can be adapted to assess the risk of intentional introductions of non-native species regardless the taxon that may or not be considered as detrimental (Andersen 2004, Baker et al. 2005, Baker et al. 2008, Schrader et al. 2010).*

The risk analysis follows a process defined by three stages : (1) the initiation process which involves identifying the organism and its introduction pathways that should be considered for risk analysis in relation to Belgium, (2) the risk assessment stage which includes the categorization of emerging non-native species to determine whether the criteria for a quarantine organism are satisfied and an evaluation of the probability of organism entry, establishment, spread, and of their potential environmental, economic and social consequences and (3) the risk management stage which involves identifying management options for reducing the risks identified at stage 2 to an acceptable level. These are evaluated for efficacy, feasibility and impact in order to select the most appropriate. The risk management section in the current risk analysis should however not been regarded as a full-option management plan, which would require an extra feasibility study including legal, technical and financial considerations. Such thorough study is out of the scope of the produced documents, in which the management is largely limited to identifying needed

1

[1] A weed or a pest organism not yet present in the area under assessment, or present but not widely distributed, that is likely to cause economic damages and is proposed for official regulation and control (FAO 2010).

actions separate from trade restrictions and, where possible, to comment on cost-benefit information if easily available in the literature.

This risk analysis is an advisory document and should be used to help support Belgian decision making. It does not in itself determine government policy, nor does it have any legal status. Neither should it reflect stakeholder consensus. Although the document at hand is of public nature, it is important to realise that this risk assessments exercise is carried out by (an) independent expert(s) who produces knowledge-based risk assignments sensu Aven (2011). It was completed using a uniform template to ensure that the full range of issues recognised in international standards was addressed.

To address a number of common misconceptions about non-native species risk assessments, the following points should be noted (after Baker et al. 2008):

2 *Risk assessments are advisory and therefore part of the suite of information on which policy decisions are based;*

3 *The risk assessment deals with potential negative (ecological, economic, social) impacts. It is not meant to consider positive impacts associated with the introduction or presence of a species, nor is the purpose of this assessment to perform a cost-benefit analysis in that respect. The latter elements though would be elements of consideration for any policy decision;*

4 *Completed risk assessments are not final and absolute. New scientific evidence may prompt a re-evaluation of the risks and/or a change of policy.*

Myriophyllum heterophyllum (Photo : Andreas Hussner).

Executive summary

PROBABILITY OF ESTABLISHMENT AND SPREAD (EXPOSURE)

- Entry in Belgium

The species was first recorded in the wild in Belgium in 1993 and is now established at a few sites (principally in Campine). The main pathway of entry is the trade for ornamental use in ponds and in aquaria with subsequent disposal of cultivated plants into the wild and possibly further natural spread.

- Establishment capacity

M. heterophyllum occurs as an aquatic plant in lakes, ponds and wetlands and can also grow in a semi-terrestrial form. The required climatic and environmental characteristics occur in Belgium and sensitive areas, nature reserves and Natura2000 sites are vulnerable to invasion. The currently limited distribution in Belgium might result from the presence of a natural control agent, the aquatic weevil *Eubrychius velutus* , the specific genetic lineages that are present or competitive plants, present here and not in north-eastern USA, or by a combination of these factors.

- Dispersion capacity

The capacity of the species to colonize new areas is clearly linked to human-mediated dispersion, mainly through trade and subsequent disposal of aquaria contents into local waterways and ponds. In non-native areas, where the species shows invasive characters, short distance dispersal through vegetative fragments is facilitated by animal vectors and human activities (transport on human clothing, footwear, machinery, boats or fishing equipment, weed cutting,..).

EFFECT OF ESTABLISHMENT

- Environmental impacts

Where the species is invasive, observed environmental impacts include habitat alteration, modification of natural benthic communities, modification of nutrient regimes, and modification of succession patterns. All those impacts can conduct locally to a reduction of native biodiversity, threat to and loss of endangered species. Some infrastructure damage and damage to ecosystem services have also been mentioned.

None of these impacts have been observed on a large scale in Belgium or in Europe yet but it could happen if the species became an aggressive invasive.

RISK MANAGEMENT

As with most of the other Invasive Alien Species, the best way to deal with the threat posed by *Myriophyllum heterophyllum* to biodiversity and society is through a combination of

preventive measures, early detection and rapid response to new incursions, with permanent management only as the last option.

It is particularly important for this species, which is not yet invasive in Europe, to prevent additional introductions of more aggressive genetic lineages, in particular potential hybrids. It is advised to amend and/or reinforce regulations in order to ban completely this species from import, personal holding and commercial trades.

Résumé

PROBABILITE D'ETABLISSEMENT ET DE DISSEMINATION (EXPOSITION)

- Introduction en Belgique

Myriophyllum heterophyllum a été enregistrée en milieu naturel en Belgique pour la première fois en 1993 ; elle est aujourd'hui établie dans plusieurs sites (en Campine essentiellement). La principale voie d'introduction de cette espèce dans notre environnement est le commerce horticole et sa vente comme plante ornementale pour les étangs et les aquariums.

- Capacité d'établissement

M. heterophyllum est une plante aquatique qui se développe dans les lacs, les étangs et les zones humides mais aussi en milieu semi-terrestre. Les caractéristiques climatiques et environnementales nécessaires à sa prolifération sont réunies en Belgique et de nombreuses zones sensibles, réserves naturelles et sites Natura 2000 peuvent potentiellement être envahis par l'espèce. Sa distribution actuellement encore limitée en Belgique pourrait être due à la présence d'un agent de contrôle naturel comme le charançon aquatique *Eubrychius velutus*, à l'absence d'une lignée génétique agressive ou à la présence d'autres espèces de plantes compétitives voire à une combinaison de ces divers facteurs.

- Capacité de dispersion

La capacité de l'espèce à coloniser de nouveaux habitats est clairement favorisée par les actions humaines, principalement par le biais du commerce et de l'élimination du contenu des aquariums dans les cours d'eau locaux et les étangs. Dans les zones exotiques où l'espèce présente un caractère envahissant, la dispersion à courte distance de fragments végétatifs de *M. heterophyllum* est facilitée par les animaux et les activités humaines (transport sur les vêtements, chaussures, outils, machines, bateaux, équipement de pêche et suite à des activités de désherbage/traitement de zones infestées).

EFFET DE L'ETABLISSEMENT

- Impacts environnementaux

Dans les habitats où l'espèce est envahissante, les impacts environnementaux observés comprennent une altération de l'habitat, une modification des communautés naturelles benthiques, une modification de la disponibilité en éléments nutritifs et une perturbation des patrons de succession écologique. Tous ces impacts peuvent mener, localement, à une réduction de la biodiversité indigène et à une menace supplémentaire sur les espèces déjà vulnérables voire leur disparition. Des dommages aux infrastructures ainsi qu'aux services écosystémiques ont déjà été mentionnés.

Aucun de ces impacts n'a encore été observé à grande échelle en Belgique ou en Europe pour l'instant mais ce pourrait être le cas si l'espèce devenait une espèce fortement envahissante.

GESTION DES RISQUES

Comme pour la majorité des autres espèces exotiques envahissantes, le meilleur moyen de traiter la menace que représente *Myriophyllum heterophyllum* pour la biodiversité et la société est de combiner différentes mesures de prévention, d'assurer la détection précoce et une réponse rapide aux nouveaux envahissements et de ne considérer la gestion que comme l'option de dernier recours.

Il est particulièrement important pour cette espèce (qui n'a pas encore de caractère envahissant en Europe) d'empêcher toute introduction de lignée génétique agressive de l'espèce (certaines souches hybrides en particulier). Il est par conséquent conseillé de modifier et/ou de renforcer les réglementations afin d'interdire complètement l'importation, la détention à titre individuel et le commerce de cette espèce.

Samenvatting

WAARSCHIJNLIJKHEID VAN VESTIGING EN VERSPREIDING (BLOOTSTELLING)

- Introductie in België

Myriophyllum heterophyllum werd in België voor het eerst waargenomen in 1993 en is nu in een beperkt aantal gebieden gevestigd. De voornaamste introductieweg is de handel in sierplanten voor vijvers en aquaria en daar op volgend het wegwerpen of uitplanten van gekweekte planten in het wild.

- Vestigingsvermogen

M. heterophyllum is een waterplant van meren, vijvers en waterlopen. Ze kan ook in een semi-terrestrische vorm groeien. De vereiste klimaat- en omgevingseigenschappen zijn in België aanwezig; kwetsbare gebieden, natuurgebieden en Natura2000 gebieden zijn kwetsbaar voor invasie. De momenteel nog beperkte verspreiding in België kan een gevolg zijn van de aanwezigheid van natuurlijke controleagentia, zoals de in het water levende snuitkever *Eubrychius velutus*, het genetisch profiel van de aanwezige planten, of concurrerende plantensoorten die niet in het noordoosten van de VS voorkomen, of een combinatie van deze factoren.

- Verspreidingsvermogen

Het vermogen van de soort om nieuwe gebieden te koloniseren hangt duidelijk samen met de verspreiding door de mens, overwegend via handel en het vervolgens werwerpen of uitplanten van aquariumplanten in waterlopen en vijvers. In gebieden waar de soort niet-inheems is en een invasief karakter vertoont, wordt de verspreiding over korte afstand door vegetatieve fragmenten in de hand gewerkt door dierlijke vectoren en menselijke activiteiten (transport op kledij en schoeisel, met machines, boten of visgerei, maaien van waterplanten, ...).

EFFECTEN VAN DE VESTIGING

- Milieu-impact

Waar de soort omvangrijke en dichte bestanden vormt kan dit leiden tot wijziging van de milieuomstandigheden (ondermeer nutriënten- en zuurstofregime), de levensgemeenschap en het voedselweb. Hierdoor kan de inheemse biodiversiteit plaatselijk afnemen met verlies van bedreigde soorten. Ook is schade aan infrastructuur en aan ecosysteemdiensten gemeld.

Dergelijke negatieve gevolgen zijn nog niet in België vastgesteld, maar kunnen optreden bij verdere verspreiding en ontwikkeling van grote populaties. In Nederland zorgt de soort reeds voor overlast.

RISICOBEHEER

Een combinatie van preventieve maatregelen, vroege opsporing en snelle reactie op initiële vestiging biedt de beste bescherming. Mechanische bestrijding is mogelijk maar mag vegetatieve verspreiding middels fragmenten niet in de hand werken. Voldoende nazorg is steeds noodzakelijk.

Eventuele bijkomende introductie van meer invasieve genetische lijnen, en hybriden dient te worden voorkomen. Het beperken of volledig verbieden van invoer, het persoonlijk bezit en de verkoop wordt daarom aangeraden.

STAGE 1: INITIATION

Present its distribution and pathways of quarantine concern that should be considered for risk analysis in Belgium. A short morphological description can be added if relevant. Specify also the reason(s) why a risk analysis is needed (the emergency of a new invasive organism in Belgium and neighboring areas, the reporting of higher damages caused by a non- native organism in Belgium than in its area of origin, or request made to import a new non-native organism in the Belgium).

1.1 ORGANISM IDENTITY

Scientific name :	*Myriophyllum heterophyllum*, Michaux 1803
Synonyms:	*Myriophyllum elatinoides* Gaudichaud-Beaupré 1825, *Potamogeton verticillatum* Walter.
Common names :	Broadleaf Watermilfoil (Eng), Twoleaf Watermilfoil (US), Variable Watermilfoil (Eng); Myriophylle hétérophylle (FR); Ongelijkbladig vederkruid (Nl); Verschiedenblättriges Tausendblatt (Ge)
Taxonomic position:	Magnoliophyta » Magnoliophyta » Rosopsida » Saxifragales » Haloragaceae »
	Myriophyllum heterophyllum

1.2 SHORT DESCRIPTION

M. heterophyllum is an aquatic plant that has submerged vegetation with emergent flowering spikes. It is a perennial, aquatic herb that has leaves of two noticeably different forms. The submerged leaves are finely dissected, whorled, reddish/greenish-brown, and 1.3-6.4 cm long. The emergent leaves are small, oval, bright green, whorled and up to 0.6 cm wide. Emergent leaves stand 15.2-20.3 cm out of the water and may not be apparent until late summer. Flowering occurs from June to September. Flowers are emergent on 5.1-30.5 cm, green to reddish stalks. Petals are less than 3 mm in length and are subtended by downward curved bracts. Fruits are small, nearly round and have a rough surface (summarized from Aiken, 1981).

A very similar Australian species (likewise with conspicuous floral bracts) is also cultivated as an ornamental in Europe, *Myriophyllum simulans* (see Jäger *et al.* 2008). It is best distinguished in having 8 stamens, not 4. It is not impossible that these two species are intermixed.

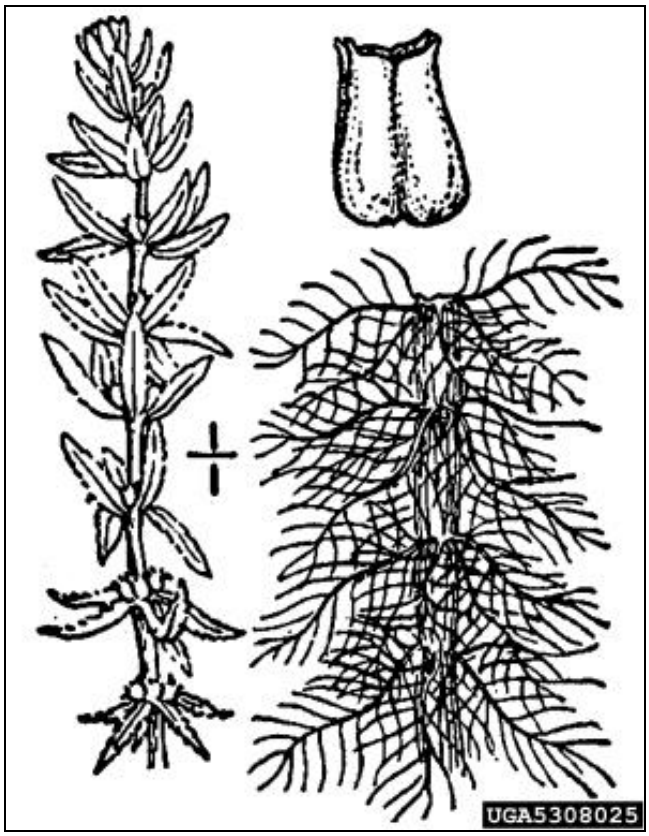

Figure 1. Submerged and emergent leaves of *M. heterophyllum* (http://www.invasive.org/browse/detail.cfm?imgnum=5308025).

1.3 ORGANISM DISTRIBUTION

Native range

The native distribution of *M. heterophyllum* is known in general, but not documented in detail. Aiken (1981) lists its distribution in North America as 'Virginia to Florida, northward to Ontario and Michigan, and westward to Missouri and Texas'.

There is no consensus on the native distribution of this species, for example USDA (United States Department of Agriculture) considers the species indigenous in Eastern North America (Canada and USA), and exotic in Western North America. But the species is usually considered as native to the eastern part of the USA, except the north-eastern region. More precisely it is considered non-native and invasive in New England, where it appears to have been introduced circa 1932 by escape from cultivation with subsequent spread via vegetative propagules (Les & Mehrhoff, 1999). Since its initial introduction to New England, it has spread throughout the region and is the most common invasive aquatic plant in New Hampshire (Thum & Lennon, 2009). It is not clear if *M. heterophyllum* was historically native to the mid-Atlantic region (Delaware, Maryland, New Jersey, New York, Pennsylvania and Virginia). For example, it is treated as a non-native invasive species in New York and eastern Pennsylvania, but is considered an extremely rare native and threatened species in nearby Delaware. Part of the confusion regarding its historical status (native/non-native) in north-eastern USA may result from confusion with the closely related species *M. pinnatum*, which

is considered native along the eastern coast from Florida through eastern Massachusetts (Aiken, 1981).

M. heterophyllum is definitively considered as non-native in western USA: while it is not clear when it was first introduced there, its recent spread in the region - especially in Washington state - is causing concern among water resource managers. Two causes for concern include the possible misidentification of *M. heterophyllum* with the closely-related, morphologically similar, and endemic western watermilfoil, *M. hippuroides*, and the potential for hybridization between the two species.

Introduced range

Belgium:

A rare, locally naturalised alien, probably overlooked. First recorded in a dead branch of river Meuse near Lives-sur-Meuse in 1993 (along with *Lagarosiphon major*; see Bouxin & Lambinon 1996) but soon disappeared from the site. Recently discovered in several canals and other artificial water courses (chiefly in Antitank-ditch, Dessel-Schoten canal) in the northern parts of Antwerpen province (De Beer & De Vlaeminck 2008). The species was probably already present there for considerable time, possibly even since the late seventies but it was thought to be *M. spicatum* at the time (Luc Denys pers. com.).

Rest of Europe:

Myriophyllum heterophyllum has been recorded in Austria, France (not established yet, first found in 2011), Germany, Netherlands and Spain, (+ Switzerland and Great Britain fide EPPO 2011, not confirmed).

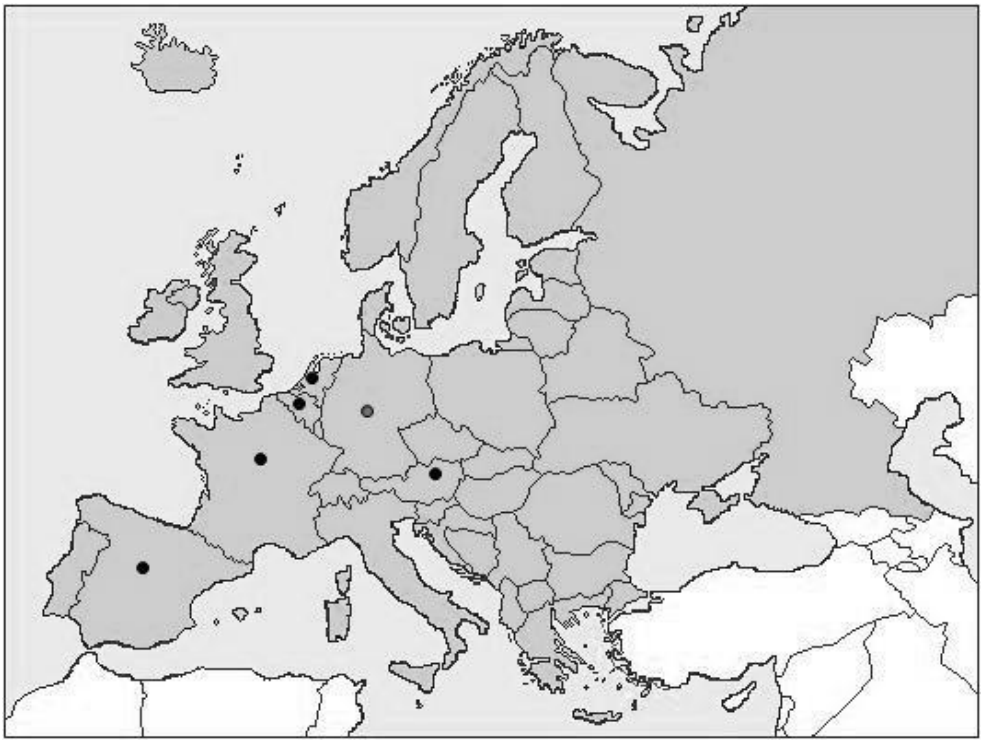

Figure 2. European countries where *Myriophyllum heterophyllum* occurs

The exact origin of European populations of *Myriophyllum heterophyllum* is rather obscure. It is known since the 1940's from Germany (Wimmer 1997, Hussner et al. 2005). Wann (1997) does not mention it as an ornamental in European gardens (see however Jäger et al. 2008). It was most likely introduced as an aquarium plant and managed to escape (from discarded aquarium contents).

Other continents:

M. heterophyllum was also introduced and is now recorded in China (Yu et al. 2003).

1.4 REASONS FOR PERFORMING RISK ANALYSIS

M. heterophyllum is highly competitive and can grow and spread rapidly, and is able to displace other submerged macrophyte species. It produces dense mats that reduce sunlight and can restrict water movement., These can results in a reduction of water quality and of available oxygen, particularly when decomposing. The low oxygen conditions can kill fish and harm other aquatic organisms. The dense mats can impede swimming, boating and fishing. Moreover in north-eastern USA dense mats along lake shorelines have been reported to reduce property values by 20-40% (EPPO, 2012). In eastern USA, the species hybridizes with the native *M. laxum*, resulting in a more aggressive hybrid *Myriophyllum heterophyllum x laxum* (Moody & Les, 2002).

Myriophyllum heterophyllum is an aquatic perennial plant native to the Southeast of the USA. The species is used in fish tanks and for ornamental purposes in ponds. Within Europe, including Belgium, its distribution is still limited. Because this plant has shown invasive behaviour where it was introduced (elsewhere in North America) it was included in the EPPO List of Invasive Alien Plants in 2012. Because its presence is still limited in Europe, this species can be considered as an emerging invader in Europe.

STAGE 2 : RISK ASSESSMENT

2.1 PROBABILITY OF ESTABLISHMENT AND SPREAD (EXPOSURE)

Evidence should be available to support the conclusion that the non-native organism could enter, become established in the wild and spread in Belgium and neighbouring areas. An analysis of each associated pathways from its origin to its establishment in Belgium is required. Organisms intentionally imported maybe maintained in a number of intended sites for an indeterminate period. In this specific case, the risk may arise because of the probability to spread and establish in unintended habitats nearby intended introduction sites.

2.1.1 Present status in Belgium

Specify if the species already occurs in Belgium and if it makes self-sustaining populations in the wild (establishment). Give detail about species abundance and distribution within Belgium when establishment is confirmed together with the size of area suitable for further spread within Belgium.

A rare, locally naturalised alien, possibly overlooked. First recorded in a dead branch of river Meuse near Lives-sur-Meuse in 1993 (along with *Lagarosiphon major*; see Bouxin & Lambinon 1996) but soon gone. Recently discovered again in several canals and other artificial water courses (chiefly in antitank-ditches, Dessel-Schoten kanaal) in the northern parts of Antwerpen province (De Beer & De Vlaeminck 2008). Most records were made from 2007 onwards, but the dimensions of some populations suggest a much longer presence. One herbarium collection (Antitank ditch near Sint-Job-in-'t-Goor) dates back to 1999. *Myriophyllum heterophyllum* appears to be firmly established in several localities but does not (yet) seem to spread in an invasive way.

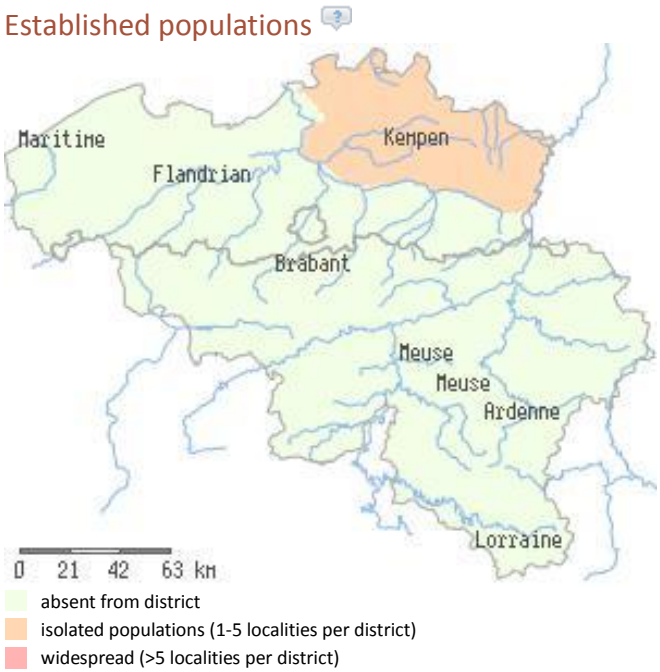

Figure 3. Established population of *Myriophyllum heterophyllum* by geographic district in Belgium. Source: http://ias.biodiversity.be

The species has also been recently recorded (30/12/2011) in one pond near Brûly-de-Pesche (Namur province) (fide Observations.be; not recorded in DEMNA database 2013).

2.1.2 Present status in neighbouring countries

- Netherlands

  Recently found (first recorded in 2001) in stagnant or slowly flowing, eutrophic or less eutrophic water systems (Luijten & Odé, 2007). Due to confusion with *M. aquaticum* by observers records are not always correctly reported and the map is possibly incomplete.

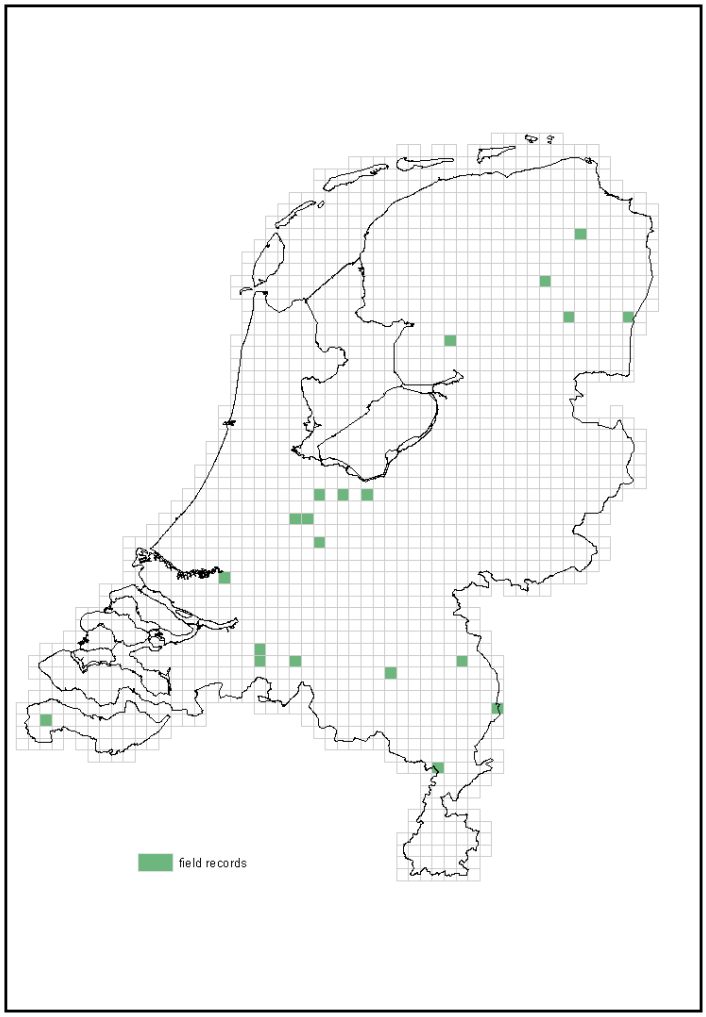

Figure 4.Distribution of *Myriophyllum heterophyllum* in the Netherlands (http://www.q-bank.eu).

- France

Myriophyllum heterophyllum is not yet firmly established in France, but it was found for the first time in 2011, in a small pond in Saint-Sylvestre (Haute-Vienne) (ANSES, 2011).

- Germany

Variable Watermilfoil is a naturalized neophyte in Germany. First recorded during the 1940's and considered established since the end of the 1950's (FloraWeb, 2009). Its present distribution and abundance seem not well documented but it is established in at least 6 Länder.

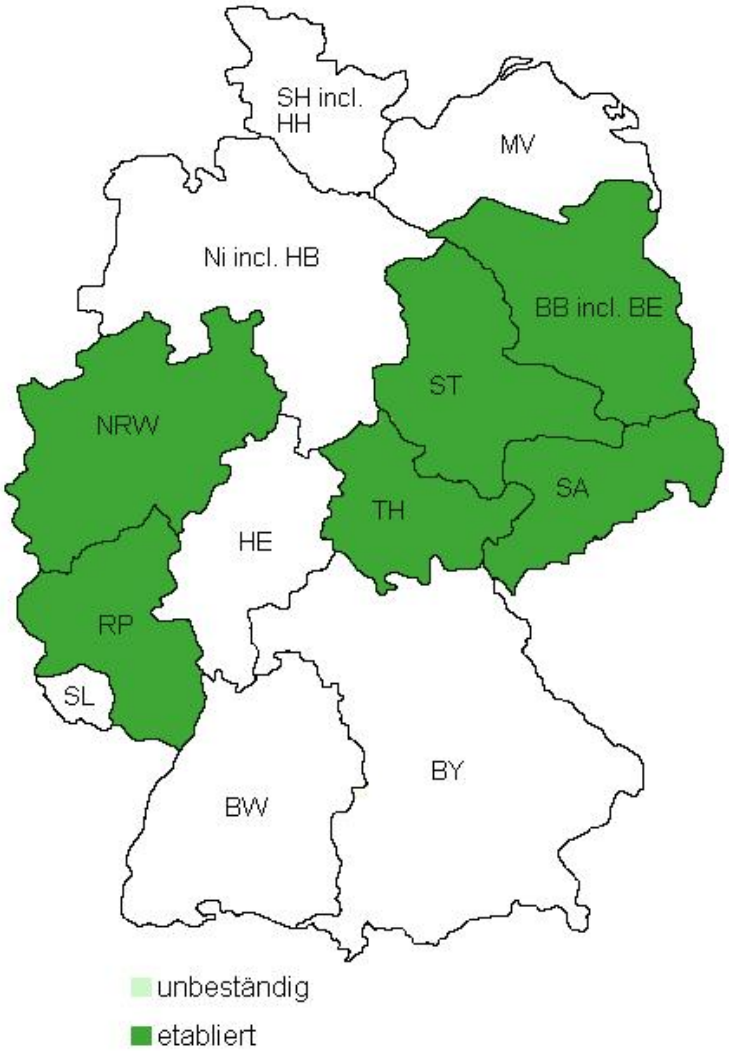

Figure 5. Distribution of *Myriophyllum heterophyllum* in Germany, Dark green = Länder where the species is established (etabliert)[2].

2

- **United Kingdom**

Myriophyllum heterophyllum has not yet been recorded in the UK (NBN gateway, 2013).

2.1.3 Introduction in Belgium

Specify what are the potential international introduction pathways mediated by human, the frequency of introduction and the number of individuals that are likely to be released in Europe and in Belgium. Consider potential for natural colonisation from neighbouring areas where the species is established and compare with the risk of introduction by the human-mediated pathways. In case of plant or animal species kept in captivity, assess risk for organism escape to the wild (unintended habitats).

Myriophyllum heterophyllum appears to be established in several localities in Europe and a few sites in Belgium but does not (yet) seem to spread in an invasive way. It is considered most likely that all occurrences in the wild derive from plants discarded when clearing out ponds.

Human-mediated pathways is the main risk of introduction. In fact, the only pathway mentioned for long distance dispersal of *Myriophyllum heterophyllum* in scientific literature is horticultural and aquarium trade. The species is widely sold as an aquarium and garden pond plant.

ENTRY IN BELGIUM
Aquarium and horticultural trade is the only introduction pathway identified. In its initial Belgian (in 1983) and European (in 1940's) localities it was most likely introduced as an ornamental plant and later managed to escape from discarded aquarium or garden debris.

2.1.4 Establishment capacity and endangered area

Provide a short description of life-history and reproduction traits of the organism that should be compared with those of their closest native relatives (A). Specify which are the optimal and limiting climatic (B), habitat (C) and food (D) requirements for organism survival, growth and reproduction both in its native and introduced ranges. When present in Belgium, specify agents (predators, parasites, diseases, etc.) that are likely to control population development (E). For species absent from Belgium, identify the probability for future establishment (F) and the area most suitable for species establishment (endangered area) (G) depending if climatic, habitat and food conditions found in Belgium are considered as optimal, suboptimal or inadequate for the establishment of a

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http://www.aquatischeneophyten.de/Bilder/Verbreitungskarten%20deutsche%20Version/Deutschlandkarte%20Myriophyllum%20heterophyllum.jpg (January 2013)

reproductively viable population. The endangered area may be the whole country or part of it where ecological factors favour the establishment of the organism (consider the spatial distribution of preferred habitats). For non-native species already established, mention if they are well adapted to the eco-climatic conditions found in Belgium (F), where they easily form self-sustaining populations, and which areas in Belgium are still available for future colonisation (G).

A/ Life-cycle and reproduction

Reproduction primarily occurs through vegetative fragmentation and rhizome division, although the plant may also reproduce by seeds remaining in lake and ponds sediments. The flowers and fruits appear from June to September (EPPO 2012). Up to now only vegetative reproduction has been observed and mentioned in Europe (Fritschler 2007, Hussner 2010).

B/ Climatic requirements[3]

In North America *M. heterophyllum* over-winters in the frozen lakes of northern climates and can thrive in warm southern water bodies. Optimal growth temperature range from 18°C to 25°C. The plant has however been found growing under a wide range of water temperatures (réf).

C/ Habitat preferences[4]

M. heterophyllum primarily occurs in lakes, ponds, large rivers and swamps, but can also grow in a semi-terrestrial form when stranded on mudflats.

Gerber and Les (1996) found *M. heterophyllum* to be associated with water bodies that had higher pH and calcium levels relative to other species of milfoils in Michigan and Wisconsin. It can be found in calcium-rich waters, but tends to prefer acid waters in Belgium (AlterIAS web site). In New Hampshire (USA), in its introduced range *M. heterophyllum* is associated with large lakes: large, low elevation lakes with relatively high pH, alkalinity and conductivity (Thum & Lennon, 2009). It is not clear whether these relationships hold true across different geographic areas where the species occurs, or among distinct genetic lineages of *M. heterophyllum*.

D/ Food habits[5]

3 Organism's capacity to establish a self-sustaining population under Atlantic temperate conditions (Cfb Köppen-Geiger climate type) should be considered, with a focus on its potential to survive cold periods during the wintertime (e.g. plant hardiness) and to reproduce taking into account the limited amount of heat available during the summertime.

4 Including host plant, soil conditions and other abiotic factors where appropriate.

5

NA

E/ Control agents

The aquatic weevil *Eubrychius velutus* is distributed throughout Europe and Asia. It is a *Myriophyllum* specialist. Native hosts are *M. verticillatum* and *M. spicatum.* It has expanded its host range to include the non–native *M. heterophyllum*. The weevil can complete all life stages on the plant by living on and consuming the meristem and leaves during larvae stage up to pupation on the stem. After hatching the adults begin feeding on the meristem and leaves (Newman *et al.* 2006).

F/ Establishment capacity in Belgium

On the basis of comparison of natural and climatic conditions prevalent in north-eastern USA, where the species is aggressively invasive, one should acknowledge that the potential establishment capacity in Belgium and in neighbouring countries is high.

Nevertheless, in Belgium *M. heterophyllum* has not yet displayed an invasive behaviour. This lag phase could be explained for reasons like differences in genetic lineages or by existing control agents or competitive plants present here and not in north-eastern USA or a combination of these factors.

For animal species only.

G/ Endangered areas in Belgium

Endangered areas

Climatic conditions (including severe frost in winter) and natural or semi-natural habitats where the species occurs in north-eastern USA are pretty similar to the ones observed in north-western Europe. If the species started to be more aggressive, all Belgian districts would present the right eco-climatic conditions and could potentially be invaded by the species :

Districts in Belgium	**Environmental conditions for species establishment**[6]
Maritime	Optimal
Flandrian	Optimal
Brabant	Optimal
Kempen	Optimal
Meuse	Optimal
Ardenne	Optimal
Lorraine	Optimal

ESTABLISHMENT CAPACITY AND ENDANGERED AREAS IN BELGIUM

M. heterophyllum **is present in the wild and partly naturalized in Belgium and in Europe but has not yet displayed an invasive behaviour. This could be explained by the presence of a natural control agent, an aquatic weevil, or differences in genetic lineages or the presence of competitive plants here but not in north-eastern USA, or a combination of these factors..**

6 For each district, choose one of the following options : optimal, suboptimal or inadequate.

2.1.5 Dispersion capacity

Specify what is the rate of dispersal once the species is released or disperses into a new area. When available, data on mean expansion rate in introduced territories can be specified. For natural dispersion, provide information about frequency and range of long-distance movements (i.e. species capacity to colonise remote areas) and potential barriers for spread, both in native and in introduced areas, and specify if the species is considered as rather sedentary or mobile. For human-assisted dispersion, specify the likelihood and the frequency of intentional and accidental movements, considering especially the transport to areas from which the species may easily colonise unintended habitats with a high conservation value.

A/ Natural spread

Like most other invasive aquatic plants, *Myriophyllum heterophyllum* is largely spread over geographically separate regions by human dispersal (mainly through the aquatic plants trade for aquaria and garden ponds (e.g. Revilla et al., 1991; Kay and Hoyle, 2001; EPPO datasheet 2011). Once established in a new locality, its spread can happen via a range of mechanisms. The plants are easily spread downstream in the form of vegetative fragments or seed (though the latter seems much less important than the former (Sidorkewicj *et al*., 2000) and seed production has not been observed in Europe yet (Fritschler 2007; Hussner 2010).

Once escaped from an aquarium or cultivated pond, *M. heterophyllum* is capable of spreading through vegetative fragments. Vegetative parts of the plant may be spread by animals especially waterfowl (via the digestive tract or attached to plumage). This is always a possible mean of transfer from one site to another. There is also possibility of dispersal by flooding events.

B/ Human assistance

M. heterophyllum is a popular plant in the aquarium and water gardening trades and can readily be obtained from any number of aquatic plant vendors under a variety of names. Plants confirmed genetically as *M. heterophyllum* have been purchased from a variety of vendors under a variety of common (myrio, foxtail, and parrotfeather) and scientific names of (*M. heterophyllum*, *M. pinnatum*, *M. tuberculatum*, *M. aquaticum*, and *M. simulans*).

Plant fragments are also easily transported attached to ships or boats. In Canada and elsewhere, quarantine measures have been introduced involving public information campaigns and boat inspections (for example at ferry landing points on Vancouver Island, British Columbia) to try to minimize transfer of plant material to un-infested river and lake systems.

DISPERSAL CAPACITY

The species capacity to colonize new areas is clearly linked to human-mediated dispersion, mainly through trade and disposal of aquaria contents into local waterways and ponds. In non-native area, where the species shows invasive characters, short distance dispersal by

vegetative means is facilitated by accidental transport on human clothes and footwear, machinery, boats or fishing equipment.

2.2 EFFECTS OF ESTABLISHMENT

Consider the potential of the non-native organism to cause direct and indirect environmental, economic and social damages as a result of establishment. Information should be obtained from areas where the pest occurs naturally or has been introduced, preferably within Belgium and neighbouring areas or in other areas with similar eco-climatic conditions. Compare this information with the situation in the risk analysis area. Invasion histories concerning comparable organisms can usefully be considered. The magnitude of those effects should be also compared with those caused by their closest native relatives.

2.2.1 Environmental impacts

Specify if competition, predation (or herbivory), pathogen pollution and genetic effects is likely to cause a strong, widespread and persistent decline of the populations of native species and if those mechanisms are likely to affect common or threatened species. Document also the effects (intensity, frequency and persistency) the non-native species may have on habitat peculiarities and ecosystem functions, including physical modification of the habitat, change to nutrient cycling and availability, alteration of natural successions and disruption of trophic and mutualistic interactions. Specify what kind of ecosystems are especially at risk.

A/ Competition

In north-eastern USA where the species is invasive, dense and extensive populations of *M. heterophyllum* cause loss of light and reduction in dissolved oxygen content. This results in a change of water quality and generally modifies the suitability of habitats for other species. By this way the plant out-competes and can displace the native aquatic flora(EPPO 2012).

B/ Predation/herbivory

NA

C/ Genetic effects and hybridization

It has been suggested that the invasive character of *M. heterophyllum* in north-eastern USA is due to heterosis or "hybrid vigor" resulting from hybridization with other *Myriophyllum* species. In Eastern USA, the species may hybridize with the native *M. laxum* resulting in a more aggressive hybrid *Myriophyllum heterophyllum x laxum* (Moody & Les 2002, in Moody & Les 2010).

Thum & Lennon (2006) question this in their article "I*s hybridization responsible for invasive growth of non-indigenous water-milfoils?"* Using nuclear ribosomal DNA, they looked for F1 hybrid populations of invasive *M. heterophyllum* in 25 New Hampshire lakes. In contrast to previous study that found F1 hybrid lineages of invasive *M. heterophyllum* in Connecticut, they did not find hybrids in their study lakes. This result has two implications: (1) pure lineages of *M. heterophyllum* are also capable of invasive growth, and (2) the distribution of invasive *M. heterophyllum* lineages (hybrid vs. pure) may be spatially structured across New England. Thum & Lennon (2006) stressed the importance

of more detailed distributional and ecological studies for understanding the invasive potential of this species. They also mentioned that it is possible that increased nutrient inputs and lake disturbances arising from increased recreational use (ie eutrophication of lakes see Lennon *et al*. 2003, as cited in Thum & Lennon 2006) might facilitate both their spread and establishment.

The absence of invasive character observed in European *M. heterophyllum* populations could also be linked with the genetic hypotheses. It is well possible that *M. heterophyllum* lineages introduced in Europe do not have the favourable characteristics of invasiveness.

Hybridization with native local *Myriophyllum sp.* has not been observed in Europe but could happen in the future. There is also a risk that, in the future, new human induced accidental introductions concern *Myriophyllum heterophyllum x laxum* or the more aggressive lineages/strains observed in north-eastern USA.

D/ Pathogen pollution

None known.

E/ Effects on ecosystem functions

In north-eastern USA *M. heterophyllum* is highly competitive and can grow and spread rapidly, and is able to outcompete other submerged macrophyte species. It produces dense mats that reduce sunlight and can restrict water movement, and particularly when in decomposition, it can reduce water quality and available oxygen. The resulting low oxygen conditions can then kill fish and harm other aquatic organisms.

ENVIRONMENTAL IMPACTS

Where the species is invasive, observed environmental impacts include habitat alteration, modification of natural benthic communities, modification of nutrient regimes, modification of succession patterns. All those impacts could locally lead to a reduction of native biodiversity, threat to and loss of endangered species. Some infrastructure damage and damage to ecosystem services have also been mentioned.

None of these impacts have been observed on a large scale in Belgium or Europe yet but it could happen if the species started to become an aggressive invasive.

2.2.2 Other impacts

A/ Economic impacts

Describe the expected or observed direct costs of the introduced species on sectorial activities (e.g. damages to crops, forests, livestock, aquaculture, tourism or infrastructures).

In north-eastern USA dense mats along lake shorelines have been reported to have reduced property values by 20-40% (by limitations on water use - recreational activities).

B/ Social impacts

Describe the expected or observed effects of the introduced species on human health and well-being, recreation activities and aesthetic values.

During extensive growth episode of the plant, dense mats on water can impede recreational use such as swimming, diving, boating and fishing.

STAGE 3 : RISK MANAGEMENT

The decision to be made in the risk management process will be based on the information collected during the two preceding stages, e.g. reason for initiating the process, estimation of probability of introduction and evaluation of potential consequences of introduction in Belgium. If the risk is found to be unacceptable, then possible preventive and control actions should be identified to mitigate the impact of the non-native organism and reduce the risk below an acceptable level. Specify the efficiency of potential measures for risk reduction.

3.1 RELATIVE IMPORTANCE OF PATHWAYS FOR INVASIVE SPECIES ENTRY IN BELGIUM

The relative importance of intentional and unintentional introduction pathways mediated by human activities should be compared with the natural spread of the organism. Make use e.g. of information used to answer to question 2.1.3.

International aquarium and horticultural trade is the only introduction pathway identified for the species entry in Belgium**.** Used as an aquarium or as an ornamental plant in garden ponds, *M. heterophyllum* is relatively rarely encountered within the plant trade in Belgium. This plant is not considered as economically important by the sector and is sold in less than 10% of nurseries/garden centers in Belgium (totally absent in the Walloon Region) (Vanderhoeve *et al.* 2006 ; Halford *et al*. 2011).

3.2 PREVENTIVE ACTIONS

Which preventive measures have been identified to reduce the risk of introduction of the organism? Do they reduce the risk to an acceptable level and are they considered as cost-effective? Specify if the proposed measures have undesirable social or environmental consequences. Consider especially (i) the restrictions on importation and trade and (ii) the use of specific holding conditions and effect of prohibition of organism introduction into the wild.

As with most of the other Invasive Alien Species, the best way to deal with the threat posed by *Myriophyllum heterophyllum* to biodiversity and society is through a combination of preventive measures, early detection and rapid response to new incursions, with permanent management only as the last option. It is particularly important for this species which is not yet invasive in Europe to prevent introduction of more aggressive taxa (genetic lineages or hybrids).

(i) Prohibition of organism importation, trade and holding

Hussner *et al*. 2010 consider that the increase in species number and abundance of aquatic plants is probably caused by enhanced trading and increased invasibility due to water eutrophication ⁄ re-oligotrophication and climate change. They proposed a trading ban for highly invasive non-indigenous aquatic plants. We agree with their proposal even if this will not stop natural spread, it should reduce the risk of further unintended entry and thus can be a major control factor. Legislation should be strengthened to ensure a ban on import and possession of potential invasive plants such as *M. heterophyllum* and closely related species.

Cultural control and sanitary measures are other actions that will effectively limit further spread of *M. heterophyllum* in the environment. In this regard, the species has already been banned in many different states of the USA. It was banned in Connecticut in 2003 (CT

invasive plants council http://nbii-nin.ciesin.columbia.edu/ipane/ctcouncil/CT_Invasive_Plant_List.htm), in Massachusetts as of January 1, 2006 (possibly earlier) (Massachusetts Dept. of Agriculture Resources http://www.mass.gov/agr/), in Maine as of September 1, 2000 (Chapter 722 H.P. 1843 – L.D. 2581 = A law in Maine designed to prevent the spread of invasive aquatic plants), in Vermont as of 2003 (Vermont Dept. of Agriculture http://www.vermontagriculture.com/), in New Hampshire (NH-DES 2007, in Glomski & Netherland 2008) and banned in the state of Washington as of 2005 (Washington Administrative Code title 16, chapter 16-750). In Europe, it is advised to amend and/or reinforce regulations in order to ban this species from personal holding and commercial trades.

(ii) Use of specific holding conditions and effect of prohibition of organism introduction into the wild

So far preventive management efforts have focused on the establishment of laws that require removing plant debris from boats and trailers (Thum & Lennon 2006). Such measures will prevent plant fragments to be disseminated and enhance further spread.

3.3 CONTROL AND ERADICATION ACTIONS

Which management measures have been identified to reduce the risk of introduction of the organism? Do they reduce the risk to an acceptable level and are they considered as cost-effective? Specify if the proposed measures have undesirable social or environmental consequences. Consider especially the following questions.

(i) Can the species be easily detected at early stages of invasion (early detection)?

In its native range *M. heterophyllum* may be confused with a number of *Myriophyllum* species. In general species of *Myriophyllum* are distinguished by characters of flowers and fruits, which may not be present. Vegetative material of *M. heterophyllum* may especially be confused with closely related species *M. humile*, *M. farwelli*, *M. pinnatum*, *M. laxum*, and *M. hippuroides*. However, misidentifications with more distantly related species also occur (Aiken, 1981; Thum et al., 2006), especially *M. verticillatum*.

Genetic identifications using the nuclear ribosomal DNA Internal Transcribed Spacer regions (ITS) have become common (Moody and Les, 2002; Thum et al., 2006). However, further work on the reliability of these markers based on much larger sample sizes is needed.

In Belgium and north-western Europe the only potentially confusing species is *M. aquaticum* due to its similar emerging stems (it is in any case another invasive species).

(ii) Are they some best practices available for organism local eradication?

The side effect of chemicals and even biological control methods can often be as detrimental or even worse for the environment, native species and human health.

The precautionary principle should be applied as a general rule.

Several practices, means of control and means of avoiding further spread and in some cases means of eradication of *M. heterophyllum* do exist:

- **Manual**: Hand-pulling or tarpauling may control infestations (Washington State Noxious Weed Control Board 2007). Hand removal and benthic mat use were more effective than cutting at eight infested lake sites in Maine (Bailey *et al*. 2008). Benthic mats are an appropriate option for thick extensive infestations, whereas hand removal is more cost-effective and more efficient in small areas with high-density infestations or for selective removal of sparse infestations in native macrophytic strands.

- **Physical**: Drawdown can also be used to control *M. heterophyllum* where applicable if it is extensive enough to prevent re-growth from seeds (EPPO 2009). This control method could have a negative impact on native plants and animals (EPPO 2009).

- **Chemical**: Similar to fluridone, newer chemicals tend to be enzyme-specific compounds with a reduced impacts on non-target species (Getsinger *et al*. 2008). Diquat dibrominde (Reward) and 2,4-D (Aqua Kleen and Navigate) are currently approved for use in most states in North America (Washington State Noxious Weed Control Board 2007). Triclopyr may be another option. Results from Getsinger *et al*. (2003) suggest that triclopyr may be efficacious against *M. heterophyllum* in the field over a wide range of concentrations and exposure times. Glomski and Netherland (2007) found that diquat at 370 µg ai L-1 for 30 hours provided good control (85%) of *M. heterophyllum* and that all rates and exposures of carfentrazone significantly reduced *M. heterophyllum* biomass, however, shoot regrowth from root crowns required follow-up applications. Fluridone and penoxsulam were also reported to control *M. heterophyllum* at rates as low as 5 and 10 µg ai L-1 respectively (Glomski & Netherland 2008).

- **Biocontrol**: Sheldon and Creed (2003) found that the North American weevil *Euhrychiopsis lecontei* being used as a biological control agent for Eurasian watermilfoil (*M. spicatum*) is a specialist herbivore which will have little impact on the survival of *M. heterophyllum*. In Europe the aquatic weevil *Eubrychius velutus* feeds on the meristem and leaves of diverse *Myriophyllum* including *M. heterophyllum* and has potential as a biological control agent. Further research is necessary in this domain.

(iii) Do eradication and control actions cause undesirable consequences on non-target species and on ecosystem services ?

The use of physical removing, drawdown, shading, introduction of control agents or herbicide treatment have resulted in eradication with various degree of success in particular situations. However, these means of control are non-specific . Either one of these actions will inevitably cause serious damage to local flora or fauna by intoxication (in case of chemical control), habitat disturbance and ecosystem service alteration. These side effects could

indeed drastically affect native submerged vegetation and aquatic fauna (fish, reptiles, amphibians, etc.).

(iv) Could the species be effectively eradicated at early stage of invasion?

Low, recently detected infestations may be successfully eradicated through careful and thorough hand-pulling or by using a tarpaulin. Great care should be taken with such methods since they can cause fragmentation of the plant and therefore may enhance its spread.

(v) If widely widespread, can the species be easily contained in a given area or limited under an acceptable population level?

Total eradication after extensive establishment is unlikely. In some particular cases (e.g. in shallow lakes in Nordrhein-Westfalen (Germany) dense stands have been successfully controlled. Benthic barriers may be used in small areas (swimming beaches, boating lanes, around docks) to restrict light and upward growth. Nevertheless, barriers can have a negative impact on benthic organisms and need to be properly maintained. Drawdown can also be used to control *M. heterophyllum* where applicable, if it is extensive enough to prevent re-growth from seeds.

BEST MANAGEMENT MEASURES

As with most of the other Invasive Alien Species, the best way to deal with the threat posed by *Myriophyllum heterophyllum* to biodiversity and society is through a combination of preventive measures, early detection and rapid response to new incursions, with permanent management only as the last option.

It is particularly important for this species, which is not yet invasive in Europe, to prevent new introduction of more aggressive taxa (genetic lineages or hybrids). It is advised to amend and/or reinforce regulations in order to ban completely this species from personal holding and commercial trades.

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