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Risk analysis of the Parrotfeather, *Myriophyllum aquaticum* (Vell.) Verdc.

Risk analysis report of non-native organisms in Belgium

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Adopted in date of : 11 March 2013

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Contents

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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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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 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

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).

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 aquaticum (Photo : Tim Adriaens, INBO).

Executive summary

PROBABILITY OF ESTABLISHMENT AND SPREAD (EXPOSURE)

- Entry in Belgium

The species was first recorded in the wild in Belgium in 1984 in a nature reserve near Aalst where it was most probably intentionally introduced as an ornamental plant or from discarded garden debris. Trade in horticulture for ornamental purpose and use in aquaria is thus considered as the main introduction pathway for this species. The species was subsequently recorded after 1995 in several new localities, mainly in Flanders but also in the two other regions

- Establishment capacity

Despite its South American origin the species seems to be well-adapted to frostbite and the first Belgian population apparently easily survived cold winters of the mid 1980's. In Belgium, climatic conditions in the lower parts of the country and habitats characteristics of most Belgian fresh water streams and ponds fit within the ecological requirements of *M. aquaticum*. Belgium is therefore a place where the probability of establishment of the species is high. Most wetlands, streams and ponds, including sensitive areas, nature reserves and Natura2000 sites are considered vulnerable to invasion. Nevertheless winter conditions in Ardenne and Lorraine districts are more extreme and should restrict the establishment and the negative impact of the species in those regions.

- Dispersion capacity

Because this is a popular horticultural species, it is often planted in garden ponds, and then discarded into natural habitats. Main dispersal in the wild is ensured by vegetative propagules or seeds. Natural vectors, especially waterfowl, either via the digestive tract or attached to plumage is also considered as a vector of propagation. Human activities can enhance dispersal by disposal of horticultural residues and accidental transport on clothing and footwear, machinery, boats or fishing equipment

EFFECT OF ESTABLISHMENT

- Environmental impacts

Worldwide observed environmental impacts include aquatic habitat alteration, modification of hydrology, modification of natural benthic communities, modification of nutrient regime, 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 noted.

RISK MANAGEMENT

As *Myriophyllum aquaticum* is available in the Belgian horticultural trade and subsequent accidental introductions into the wild are likely to occur, a ban on import, trade holding and cultivation would reduce the risk of further unintended entry and be a major control factor.

Since chemical weed control in an aquatic environment is extremely restricted in Belgium and because it could have strong detrimental effects on biodiversity, environment at large and human health the practical control options should focus on prevention and non-chemical methods.

Effective management of this species for eradication is relatively difficult. Mechanical control tends to remove very large amounts of material in a relatively short period of time, but due to the rapid regeneration of fragments of leaves, shoots and roots, re-colonisation is inevitable within weeks. Small, recently detected infestations may be successfully eradicated through careful and thorough hand-pulling or using a tarpaulin. Continuous efforts should be made to remove plants as soon as they reappear after mechanical control to prevent re-infestation and dominance of the habitat.

Résumé

PROBABILITE D'ETABLISSEMENT ET DE DISSEMINATION (EXPOSITION)

- Introduction en Belgique

Myriophyllum aquaticum a été enregistrée pour la première fois en Belgique en 1984 dans une réserve naturelle près d'Alost où elle avait probablement été délibérément introduite. Le commerce horticole de cette plante et son utilisation dans les aquariums sont considérés comme les principales voies d'introduction de l'espèce dans notre environnement. L'espèce a ensuite été enregistrée après 1995 dans plusieurs nouveaux endroits, principalement en Flandre mais aussi dans les deux autres régions.

- Capacité d'établissement

Malgré ses origines sud-américaines, cette espèce semble s'être bien adaptée au gel et la première population belge a de toute évidence facilement survécu aux hivers froids du milieu des années 1980. En Belgique, les conditions climatiques de la moitié nord du pays et les caractéristiques des habitats de la plupart des cours d'eau et des étangs correspondent aux exigences écologiques de *M. aquaticum.* Par conséquent, la probabilité d'établissement de l'espèce est élevée en Belgique. La majorité des zones humides, des cours d'eau et des étangs (y compris les zones sensibles, les réserves naturelles et les sites Natura 2000) sont vulnérables à l'envahissement par cette espèce. Les conditions hivernales plus extrêmes des districts de l'Ardenne et de la Lorraine devraient (pour l'instant) limiter l'établissement et l'impact négatif de l'espèce dans ces régions.

- Capacité de dispersion

Etant donné que l'espèce est communément vendue dans le commerce horticole pour l'ornementation des pièces d'eau de jardin, elle se retrouve fréquemment introduite dans les habitats naturels environnants lors de l'élimination des déchets de jardin. Une fois introduite, sa principale voie de dispersion est la production de graines et la dissémination de propagules végétatives. Des vecteurs de propagation naturels sont également considérés comme par exemple les oiseaux aquatiques, qui dispersent les graines (par endozoochorie ou épizoochorie). Les activités humaines peuvent également favoriser la dispersion des propagules et des graines lors de transports accidentels sur les vêtements, chaussures, outils et machines, bateaux ou équipement de pêche.

EFFET DE L'ETABLISSEMENT

- Impacts environnementaux

Les impacts environnementaux (observés dans le monde) comprennent une altération de l'habitat aquatique, la perturbation de l'hydrologie et des communautés naturelles benthiques, la modification de la disponibilité des éléments nutritifs et la modification 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, ou à leur disparition. Des dommages aux infrastructures ainsi qu'aux services écosystémiques ont déjà été notés.

GESTION DES RISQUES

Etant donné que *Myriophyllum aquaticum* est disponible dans le commerce horticole et que son introduction accidentelle subséquente dans la nature est fort probable, l'interdiction d'importation, de commerce, de détention et de culture de cette espèce pourrait réduire les risques d'introduction non intentionnelle dans l'environnement et constituer un facteur de contrôle majeur de ses populations.

La lutte chimique contre les mauvaises herbes dans les environnements aquatiques étant extrêmement limitée en Belgique (en raison de ses effets délétères importants sur la biodiversité, l'environnement au sens large et la santé humaine) les options pratiques de contrôle doivent mettre l'accent sur la prévention et les méthodes de contrôle non chimiques.

Une gestion efficace de cette espèce en vue de son éradication est relativement difficile à mettre en place. Le contrôle mécanique semble permettre l'élimination de grandes quantités d'individus sur un laps de temps relativement court mais en raison de la régénération rapide de la plante à partir des fragments de feuilles, de tiges et de racines, une recolonisation rapide (quelques semaines suffisent) est le plus souvent inévitable. De petites invasions détectées récemment peuvent être éradiquées avec succès par un arrachage manuel soigneux et une mise sous bâche. Les individus se régénérant après l'arrachage mécanique doivent être continuellement éliminés afin de prévenir une nouvelle invasion et éviter qu'elle ne supplante à nouveau les espèces indigènes.

Samenvatting

WAARSCHIJNLIJKHEID VAN VESTIGING EN VERSPREIDING (BLOOTSTELLING)

- Introductie in België

De soort werd in België voor het eerst waargenomen in 1984 in een natuurgebied bij Aalst waar ze hoogstwaarschijnlijk opzettelijk als waterplant of als weggeworpen tuinafval werd geïntroduceerd. De handel voor sierdoeleinden en gebruik in aquaria wordt beschouwd als voornaamste introductieweg voor deze soort. Na 1995 werd de soort op verschillende nieuwe plaatsen gedetecteerd, overwegend in Vlaanderen maar ook in de twee andere gewesten.

- Vestigingsvermogen

Hoewel afkomstig uit Zuid-Amerika lijkt deze soort zich bijzonder goed aan Belgische winters te hebben aangepast. De eerste Belgische populatie overleefde de koude winters medio jaren 1980 probleemloos. De klimaatomstandigheden in Laag-België en de habitateigenschappen van de meeste Belgische waterlopen en vijvers beantwoorden perfect aan de ecologische vereisten van *M. aquaticum*. Het is daarom erg waarschijnlijk dat de soort zich in België zal vestigen. De meeste waterrijke gebieden, stromen en vijvers, waaronder gevoelige gebieden, natuurgebieden en Natura2000 gebieden worden beschouwd als kwetsbaar voor invasie. De winteromstandigheden in de districten van de Ardennen en Lotharingen zijn meer extreem en zouden de vestiging en de negatieve impact van de soort in die regio's moeten beperken.

- Verspreidingsvermogen

Haar populariteit in de tuinbouw zorgt ervoor dat de soort vaak geplant wordt in tuinvijvers en vervolgens in de natuurlijke habitat gedumpt. De voornaamste verbreiding in het wild gebeurt via vegetatieve propagulen of zaad. Er wordt aangenomen dat ook natuurlijke vectoren, met name watervogels, via het spijsverteringskanaal of door aanhechting op de veren, kunnen bijdragen aan de verspreiding. Ook menselijke activiteiten kunnen de soort verspreiden, met name het wegwerpen van tuinbouwresiduen en onopzettelijk transport van plantfragmenten op kledij of schoeisel, werktuigen, boten of visgerei.

EFFECTEN VAN DE VESTIGING

- Milieu-impact

De wereldwijd geobserveerde impact op het milieu omvat wijzigingen van het aquatische habitat, veranderingen van de hydrologie, veranderingen van natuurlijke bentische gemeenschappen, wijziging van het nutriëntenregime en impact op de stroomsnelheid. Dit kan leiden tot een plaatselijke vermindering van de inheemse biodiversiteit, een bedreiging voor en een verlies van bedreigde soorten veroorzaken. Anderzijds werd ook schade aan infrastructuur en aan ecosysteemdiensten opgemerkt.

RISICOBEHEER

Aangezien *Myriophyllum aquaticum* in België in de tuinbouwsector beschikbaar is en de kans op onopzettelijke introductie in het wild ervan bijzonder groot is, zou een verbod op de invoer, het commercieel bezit en cultiveren ervan het risico op onopzettelijke introductie kunnen temperen en bijdragen tot een meer verregaande controle van de soort.

Omdat chemische onkruidbestrijding in een aquatisch milieu in België aan verregaande beperkingen onderworpen is en omwille van de erg schadelijke effecten ervan op de biodiversiteit, het milieu in ruime betekenis en op de volksgezondheid moeten focussen op preventie en niet-chemische methodes.

Een doeltreffend beheer voor de uitroeiing van deze soort is moeilijk. Bij mechanische bestrijding kunnen op een relatief korte termijn grote hoeveelheden materiaal verwijderd worden, maar door de snelle regeneratie van fragmenten van bladeren, scheuten en wortels kunnen in enkele weken tijd nieuwe kolonies ontstaan. Kleine, recent opgemerkte woekeringen kunnen met succes uitgeroeid worden door de planten zorgvuldig en grondig manueel uit te trekken of door ze af te dekken met een waterdicht jutekleed. Zodra de plant na mechanische controle opnieuw opduikt, moet ze aanhoudend verwijderd worden om nieuwe besmettingen en dominantie binnen de habitat te voorkomen.

STAGE 1: INITIATION

1.1 ORGANISM IDENTITY

Scientific name :	*Myriophyllum aquaticum*
Synonyms:	*Enydria aquatica* Vell.; *Myriophyllum aquaticum* (Velloso) Verdc.; *Myriophyllum brasiliense* Camb.; *Myriophyllum proserpinacoides* Gillies ex Hook. & Arn.
Common names :	Parrot feather Watermilfoil, Parrot's feather, Water Feather, Brazilian Water Milfoil (Eng.); Myriophylle aquatique, Millefeuille aquatique, Millefeuille du Brésil, Myriophyllum variété verte (Fr.); Parelvederkruid, gepareld vederkruid, Braziliaans vederkruid (Nl); Brasilianisches Tausendblatt (Ge)
Taxonomic position:	Magnoliophyta » Magnoliophyta » Rosopsida » Saxifragales » Haloragaceae » Myriophyllum aquaticum

Note that *M. brasiliense* even if considered as a synonym by taxonomist is often considered a different species in the trade and is described as less cold tolerant than *M. aquaticum*.

1.2 SHORT DESCRIPTION

Parrot feather Watermilfoil is a perennial aquatic plant. Parrot feather gets its name from its feather-like leaves that are arranged around the stem in whorls of four to six. The plant has whorls of feathery blue-green to waxy grey-green leaves deeply cut into many narrow lobes. The emergent stems and leaves are the most distinctive trait of parrot feather, as they can grow up to a foot above the water surface and look almost like small fir trees. The woody submerged stems grow over 150 cm long and will extend to the bank and shore. Attached to the Parrot feather are pinkish-white flowers that extend approximately 0.15 cm long. Flowering is not common in Belgium but in other areas as the water warms in spring, parrot feather begins to flourish. Most plants flower in the spring; however, some also flower in autumn. In Europe almost all plants of this species are female, in fact there are no male plants found outside South America. Seeds are not produced in any North American or European plants. Parrot feather reproduces asexually. New plants grow from fragments of already rooted plants.

1.3 ORGANISM DISTRIBUTION

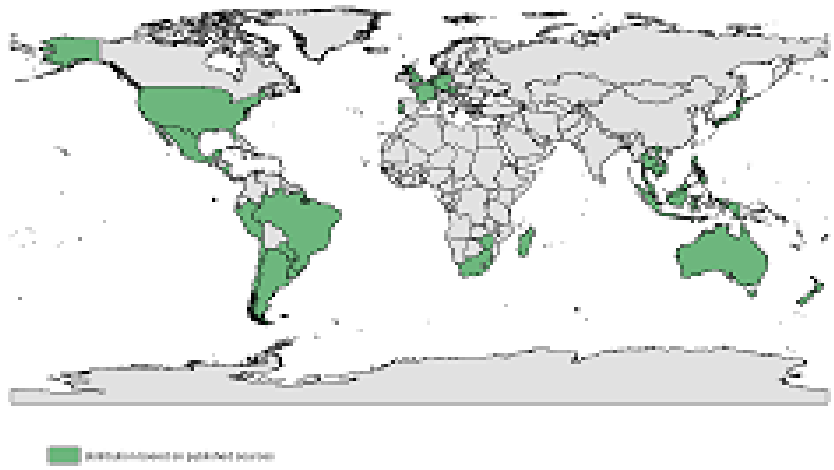


Fig 1. World Distribution map of *Myriophyllum aquaticum* (from Q-Bank fact sheet)

Native range

M. aquaticum is indigenous to South America (Orchard, 1981; Sutton, 1985) where it is more widely spread in warm areas rather than in hotter tropical regions: especially recorded in Argentina (as far south as northern Patagonia), Chile, Paraguay, Peru and southern Brazil, but also recorded in Uruguay, Bolivia and Colombia (Steubing et al., 1980; Claps 1991; Fernández et al., 1993; Leon et al., 1998; Maine et al., 1998; Nunez et al., 1998; Sabbatini et al., 1998; Ritter and Crow, 1999; Schessl, 1999; Pitelli et al., 2000; Schmidt-Munn and Posada, 2000; Maltchik et al., 2005). Although usually benign in its native range, *M. aquaticum* can and does cause weed problems in South America (Fernandez et al., 1993). It is a problematic species in reservoirs in Brazil as far north as Rio de Janeiro State (e.g. Kissman and Groth, 1995; Bini et al., 1999; Pitelli et al., 2000).

Introduced range

Belgium:

M. aquaticum was collected for the first time in Louvain-la-Neuve in 1983 (Scavée du Biéreau) where it had obviously been introduced intentionally. Perhaps first recorded in the wild in 1984 in Osbroek nature reserve in Aalst (Verloove 2002) and in 1987 in Kasterlee (Oude Hofloop) (as *Myriophyllum* spec.). However, the spread and naturalisation of *M. aquaticum* was confirmed only around 1995 when several new localities came to light, mainly in Flanders: Genk, Lanaye and Uikhoven, soon afterwards (1999) also in Ieper, Jonkershove, Kerkhove, Kortrijk and Willebroek (Verloove & Vanhecke 2000). From then it was reported from numerous new localities (Verloove 2002) and it is

now present in large parts of Flanders (but usually rather scattered; see Verloove 2006), in Brussels region and in at least 20 localities in Wallonia (fide observations.be). *Myriophyllum aquaticum* increasingly grows in nature reserves (for instance in “Langdonken” in Herselt - Aarschot, in “Réserve naturelle domaniale de l'Oseraie” in Lanaye and Natagora Nature reserve “la Marliere” in Peissant) and in natural, vulnerable water courses (for instance Kleine Nete, or Ry de Rome in Petigny).

Rest of Europe:

M. aquaticum causes severe problems in southern Europe (Portugal and France; Teles and Pinto da Silva, 1975; Costa et al., 1999; Moreira et al., 1999; Catarino et al., 2001; Peltre and Muller, 2002; Rebillard et al., 2002; Tabacchi and Planty-Tabacchi, 2002). It occurs and occasionally causes problems in cooler regions of central Europe (Austria, Germany) and the British Isles (Bank-Signon and Patzke, 1988; Dawson, 1993; Clarke and Newman, 2002), with a trend towards increasing severity and occurrence of infestations, possibly associated with an observed trend towards warmer winters.

Other continents:

It is now regarded as a major international aquatic weed, having been introduced to much of the warm-temperate to sub-tropical regions of the world (Randall, 2002). The weed is aggressively spreading in southern Africa, as far north as Zambia (Child, 1992; Chikwenhere, 1994, 2001; Mitchell, 1995; Ramoeli, 1995; Henderson and Cilliers, 2002; Foxcroft and Richardson, 2003; Cook, 2004; ECZ, 2004). It causes severe problems in the southern states of the USA (and increasingly as far north as Oregon, Washington and New England (Nelson and Couch, 1985; Anderson, 1993; Anon, 2001; Perkins et al., 1995; McCann et al., 1996; Bossard et al., 2000; Robinson, 2002; Parsons et al., 2003), New Zealand and Australia (Muyt, 2001; Champion and Clayton, 2003; Roy et al., 2004). It was designated a Rank A Invasive Alien Species (i.e. included among the 16 most invasive weeds) in Japan in 2004 (Muranaka et al., 2005). It is also present in South-East Asia (southern China, Cambodia, Indonesia (Java), Malaysia, Philippines, Thailand, Vietnam).

1.4 REASONS FOR PERFORMING RISK ANALYSIS

The characteristics that indicate its invasiveness are typical of many aquatic weeds: high growth rates, adaptability to prevailing nutrient conditions, very effective vegetative propagation, plasticity in growth response, overwintering to avoid low temperature stress, resistance to herbivory, resistance to chemical control, and absence of specific pests and diseases in introduced environments.

It is mostly found in ponds, but it has also been found in reservoirs, gravel pits, streams, canals and ditches. It is most often found in eutrophic water bodies. In contrast to other members of the genus, which are native to Europe, it is able to grow as a terrestrial plant when ponds dry out and it has even been found growing on dry bank sides.

M. aquaticum is a native of the Amazon River in South America, but has naturalized worldwide, especially in the warmer climates (Department of Ecology, State of Washington, 2009). It was first

found in Europe (France) in 1880 and in Britain in 1960. It is now found in more than 300 sites in the UK (Centre for Ecology and Hydrology, 2004). The species is known from a number of sites in others regions in Europe but it has not displayed, so far, the same tendency to proliferation as it has in Britain or France.

STAGE 2 : RISK ASSESSMENT

2.1 PROBABILITY OF ESTABLISHMENT AND SPREAD (EXPOSURE)

M. aquaticum was first found in Europe in around 1880 near Bordeaux (France) where its invasive nature was noticed in 1913, and it was recorded first in the UK in 1960. The first record in North America was in 1890 in New Jersey and it had reached Washington by 1944. *M. aquaticum* was recorded in South Africa by 1919, Japan in 1920, New Zealand in 1929 and Australia in the 1960s. It is a problem weed in its native South America continent (Fernandez et al., 1993) and it is aggressively spreading in Southern Africa, South East Asia, USA (Anderson, 1993) and Portugal (Teles and Pinto da Silva, 1975).

2.1.1 Present status in Belgium

Collected for the first time in Louvain-la-Neuve in 1983 (Scavée du Biéreau), where it was obviously introduced intentionally, *M. aquaticum* now seems to be firmly established in northern Belgium at least (see fig 2.). Perhaps first recorded in the wild in 1984 in the nature reserve Osbroek in Aalst (Verloove 2002) and in 1987 in Kasterlee (Oude Hofloop) (as *Myriophyllum* sp.). However, the spread and naturalisation of *M. aquaticum* only started around 1995 when several new localities became known, mainly in Flanders: Genk and Uikhoven, soon afterwards (1999) also in Ieper, Jonkershove, Kerkhove, Kortrijk and Willebroek (Verloove & Vanhecke 2000). From then on the plant was reported from numerous new localities (Verloove 2002) and it is now present in large parts of Flanders (but usually rather scattered; see Verloove 2006). *Myriophyllum aquaticum* grows now increasingly in nature reserves (for instance in Langdonken in Aarschot, in “Réserve naturelle domaniale de l'Oseraie” in Lanaye and Natogra Nature reserve “la Marliere” in Peissant) and in natural, vulnerable water courses for instance Kleine Nete and Ry de Rome (Petigny). The species is also present in Brussels Region (at least three sites: Moeraske (Evere), Erasmus zoning (Anderlecht) and Watermael-Boisfort (fide observations.be) In the Walloon Region it is still rather rare but it is increasingly present, with locally naturalised escape from, or relic of, cultivation in at least 20 localities (DEMNA database).

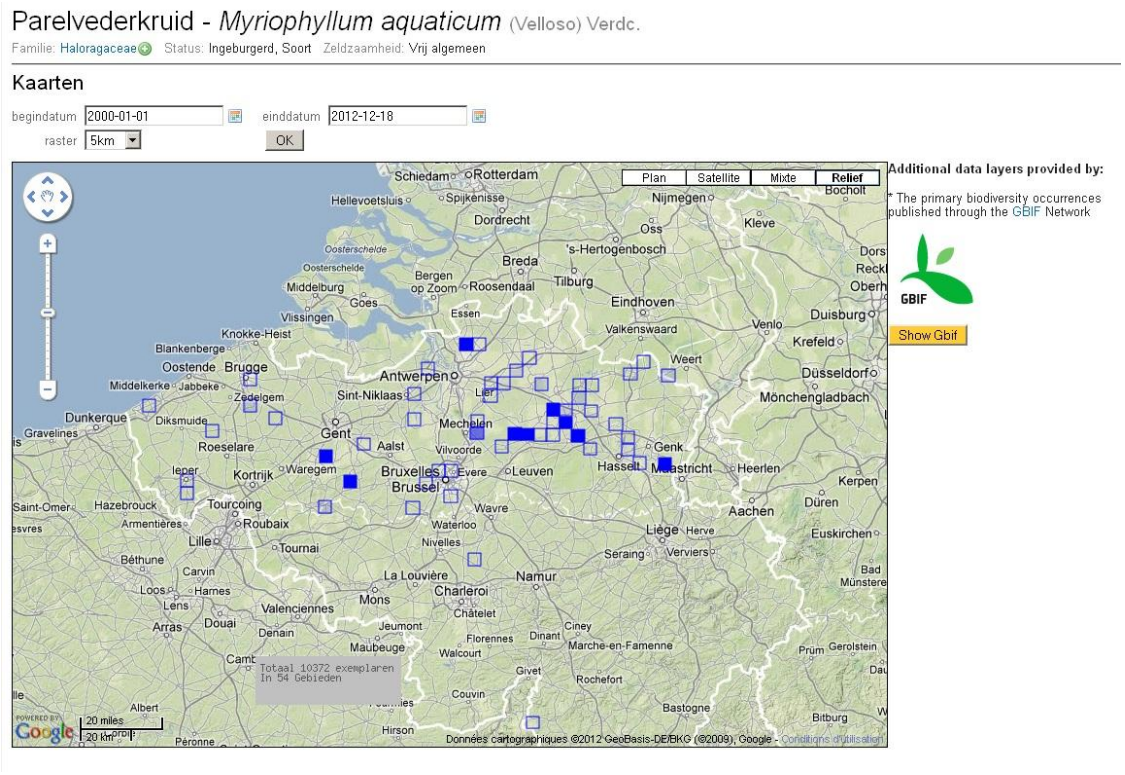


Fig 2. Distribution of *Myriophyllum aquaticum* in Belgium (fide observations.be, 2000-2012 data)

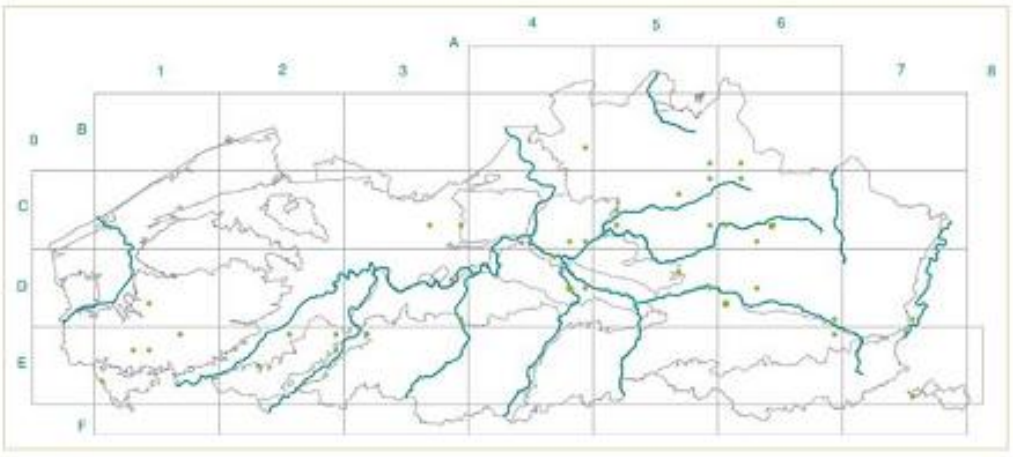


Fig 3. Distribution of *Myriophyllum aquaticum* in Flanders (Denys et al., 2004)

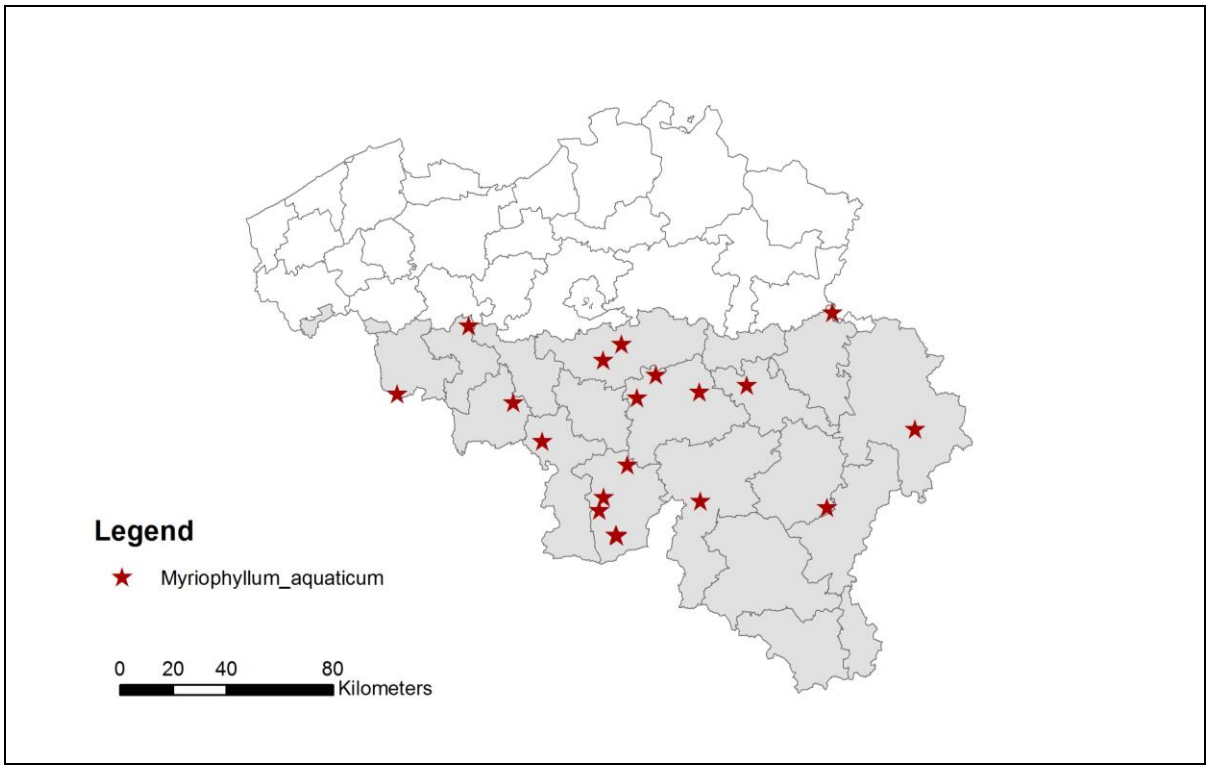


Fig 4. Distribution of *Myriophyllum aquaticum* in Wallonia (based on DEMNA data: 2000-2012)

2.1.2 Present status in neighbouring countries

Myriophyllum aquaticum is present in all countries neighbouring countries to Belgium except in Luxemburg.

- The Netherlands

Myriophyllum aquaticum was first recorded in the Netherlands in the 1990s according to the National Database Flora and Fauna[2] and is now a relatively widespread invasive in The Netherlands in shallow, eutrophic water of ponds, ditches, channels and canals.

[2] some herbarium vouchers, stored at Leiden, indicate an earlier presence of the species in the Netherlands

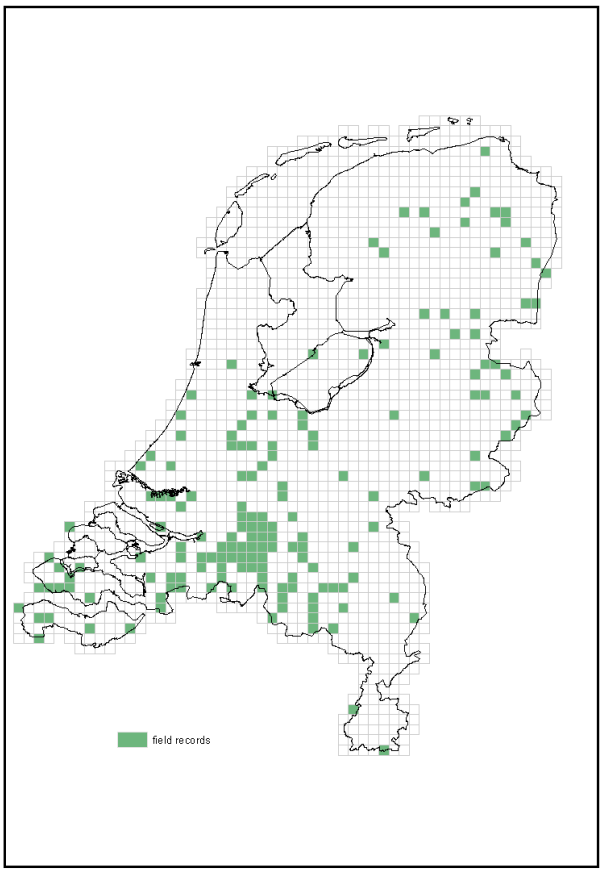


Fig 5. Distribution of *Myriophyllum aquaticum* in the Netherlands (from Q-Bank fact sheet December 2012)

- France

First introduced in France around 1880, the species was already considered as an invasive species in 1913 in Marais de Bruges (North of Bordeaux). The species is now widespread, especially along the southern Atlantic cost, from Bretagne to Aquitaine.

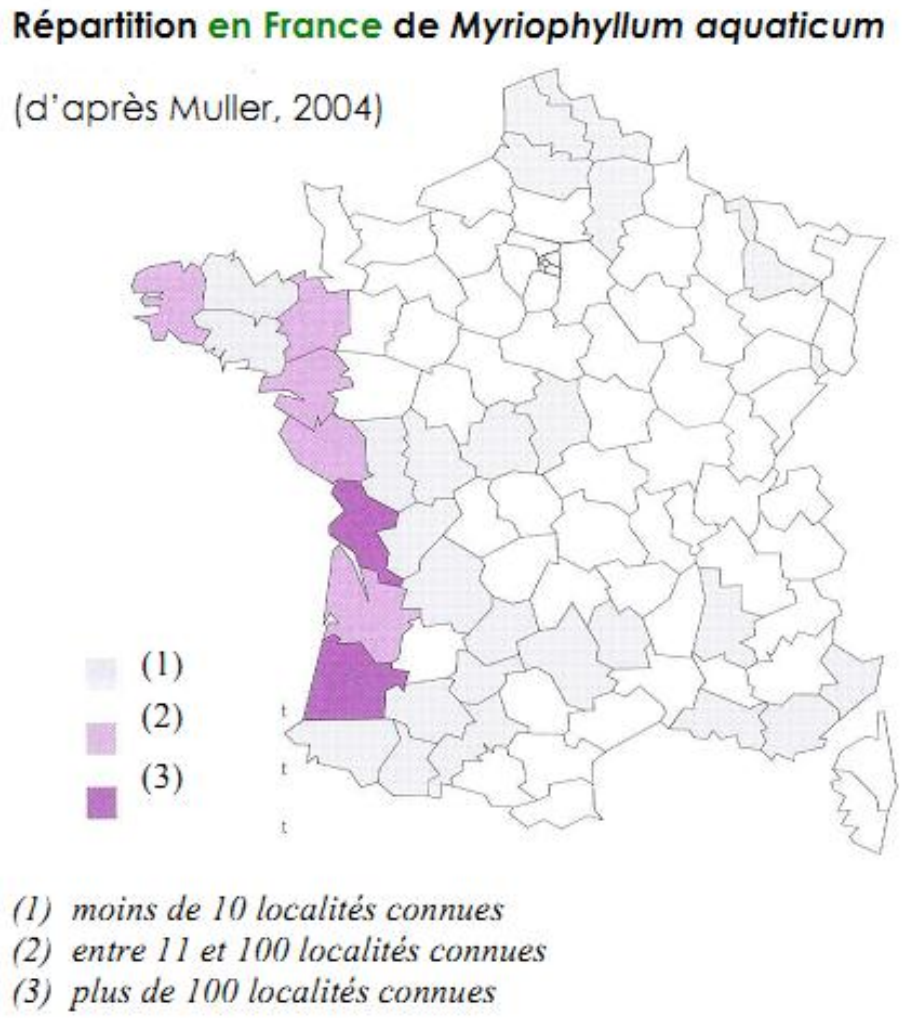


Fig 6. Distribution of *Myriophyllum aquaticum* in France (from Muller, 2004, situation in the early 2000's) and in North-western France (from Levy *et al*. 2011, situation in 2010-2011)

- Germany

The species was first recorded in Germany in 1988 in Nordrhein-Westfalen (Bank-Signon & Patzke, 1988). It has since been observed in Bayern.

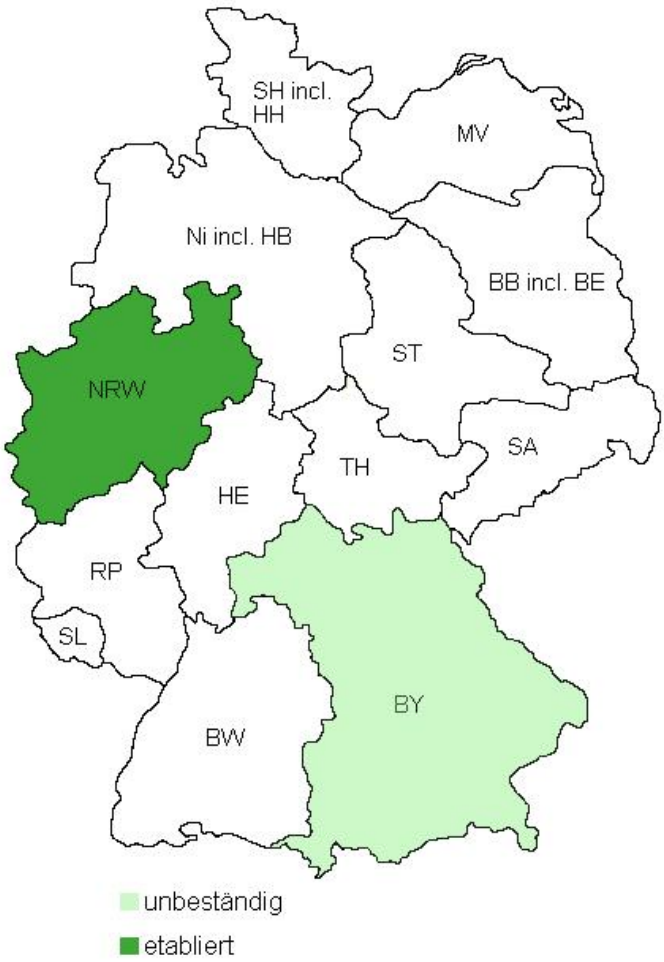


Fig 7. Distribution of *Myriophyllum aquaticum* in Germany, Länder where the species is now established (dark green : etabliert) or unsettled (light green : unbeständig)[3]

[3] http://www.aquatischeneophyten.de/Bilder/Verbreitungskarten%20deutsche%20Version/Deutschlandkarte%20Myriophyllum%20aquaticum.jpg

- United-Kingdom

This species, which has been cultivated in water gardens in Britain since 1878, was first recorded in the wild in 1960 in Surrey and in 1969 in E. Sussex. In Ireland it was first seen in Co. Down in 1990. It is now found in more than 300 (400?) sites in the UK, mostly in ponds, but it has also been found in reservoirs, gravel pits, streams, canals and ditches. It is most often found in eutrophic water bodies.

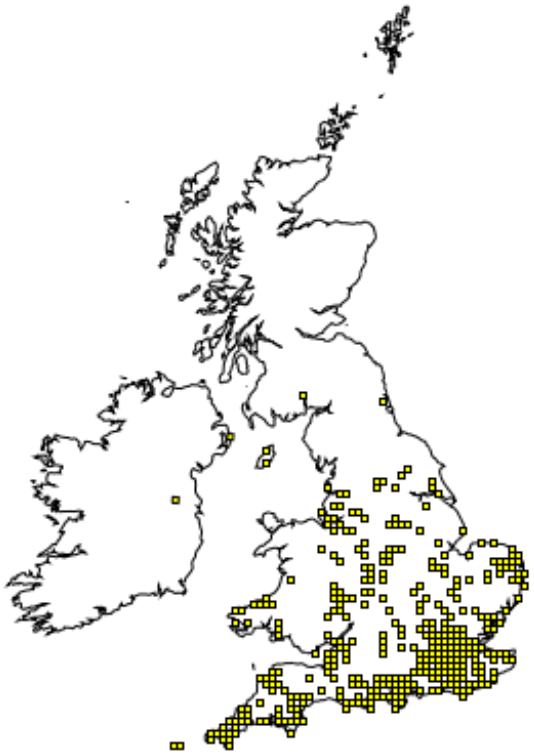


Fig 8. Distribution of *Myriophyllum aquaticum* in the UK according to records (10 km square) accessible through the NBN Gateway 2012

2.1.3 Introduction in Belgium

Long distance dispersal of the species is considered to be mainly achieved through the aquatic plants trade for aquaria and ponds. The species is usually deliberately introduced through human intervention, because this is a popular horticultural species and it is often planted in garden ponds, and has been accidentally discarded from there into natural habitats. In fact *M aquaticum* is the most commonly found aquatic invasive plant in “horticultural shops” in Belgium, more than 20% of them commercialize the species (see Halford et al., 2011).

Transfer by large wildfowl is also possible (but not documented). It was first recorded in Belgium in a small private ponds and new discoveries are often made in (very) small private ponds as well. In most of these initial localities it was probably intentionally introduced (as an ornamental plant or from discarded garden debris).

Myriophyllum aquaticum is very competitive and highly invasive, especially in moderately disturbed (polluted) water bodies. Despite its South American origin it seems to be well-adapted to frostbite: it apparently easily survived the cold winters of the mid 1980's in Osbroek nature reserve in Aalst (Verloove, 2002) and the same was also true for the cold winters of 2008-2009 and 2009-2010.

ENTRY IN BELGIUM The species was first recorded in the wild in Belgium in 1984. It was most probably intentionally introduced (as an ornamental plant or from discarded garden debris) in a nature reserve near Aalst. In most of its initial localities it was probably intentionally introduced as well (again as an ornamental plant or from discarded garden debris).

Despite its South American origin the species seems to be well-adapted to frostbite and the first Belgian population apparently easily survived cold winters of the mid 1980's. Subsequently the species was recorded after 1995 to several new localities, mainly in Flanders but also in the two other regions.

2.1.4 Establishment capacity and endangered area

The species displays many invasiveness traits. It is abundant in its broad native range, benefits from human association (i.e. it is a human commensal), it is fast growing, it has a high reproductive potential and can reproduce asexually with propagules that can remain viable for more than one year. With these characteristics, it proved invasive, inside and outside its native range; it is also a long lived species, pioneering in disturbed areas, tolerant to shade and it tolerates or even benefits from mutilation.

A/ Life-cycle and reproduction
In most of its introduced range, including in Belgium, male plants appear to be absent, and the plant's non-sexual dispersal (via stem fragments) is rapid.

Its stems may float out over the surface to form dense tangled rafts of plant material, from which the emergent shoots arise to present an impenetrable weed matt, which represents a serious problem. Small fragments root easily in mud and establish new populations: even in its native range, vegetative propagation seems to be much more important than seed production as a means of dispersal (e.g. Sidorkewicj et al., 2000).

B/ Climatic requirements[4]
M. aquaticum is associated with the temperate to tropical deciduous forests (extending to temperate steppes) vegetation zones. In its native South America, it prefers warm (cooler?) areas, such as in Argentina, Chile, Peru and southern Brazil, over hotter tropical regions (Fernández et al., 1993). Warm, shallow water and eutrophic conditions favour the growth of *M. aquaticum* (Sutton, 1985), and the species has a physiological temperature optimum at 27-37 ° C and prefers high light intensity

[4] 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.

(Hussner 2009). It can withstand considerable desiccation (Cook, 2004). Summarising, it can be assumed that *M. aquaticum* can grow well under current and likely future central (and western) European climate conditions (Hussner 2009).

M. aquaticum is associated with areas characterized by a warm to hot wet summer and a cool to warm winter. It is hardy only to climatic zone 10 (-1 to 4°C) and at present, Belgian climate is outside the physiological optimum for *M. aquaticum* but future probable global climatic changes could modify this situation.

C/ Habitat preferences[5]

M. aquaticum is found in freshwater lakes, ponds, streams, and canals and appears to be adapted to high nutrient environments. It tends to colonize slowly flowing or still water rather than water bodies with higher flow rates. While it grows best when rooted in shallow water, it is known to occur as a floating plant in the deep water of nutrient-enriched lakes. The emergent stems can survive on wet banks of rivers and lake shores, so it is well adapted to moderate water level fluctuations. The species prefers nutrient-rich conditions in very wet soils, but can also thrive in dry and nutrient-poor substrates (Hussner et al. 2009).

M.aquaticum is a fresh water species, but it is nevertheless moderately resistant to salinity (Haller et al., 1974), growing well at 3.3 parts per thousand salinity, but it is killed when salinity reaches 10 parts per thousand.

In its native range it is mainly found growing in low-lying areas, in shallow waters and on muddy substrates, but it can also reach and survive up to 1900 m in altitude in Brazil and 3250 m in Peru. It is typically found in floodplain lagoons and backwater habitats of major rivers such as the Paraná in Brazil, and it is listed as a weed in lakes, ponds, marshes, fens and irrigation channel systems in Argentina and Brazil, while in lakes and ponds only in Chile (Fernandez et al., 1993).

D/ Food habits[6]

NA

E/ Control agents

Cattle, fish and waterfowl graze the shoots, but no specific natural control agents have been detected within introduced range of the species. In particular the aquatic weevil *Eubrychius velutus* which has expanded its host range to *M. heterophyllum* (Newman et al. 2006) is not known to consume *M. aquaticum*.

F/ Establishment capacity in Belgium

There is a lack of direct information for Belgium, but globally *Myriophyllum* species, like most other invasive aquatic plants, are largely spread over geographically separate regions through human-mediated dispersal (mainly through the aquatic plants trade for aquaria and garden ponds (e.g. Revilla et al., 1991; Kay and Hoyle, 2001; Allison, 2003; Gregory, 2003). Once established in a new

[5] Including host plant, soil conditions and other abiotic factors where appropriate.

[6] For animal species only.

locality, they spread through 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]).

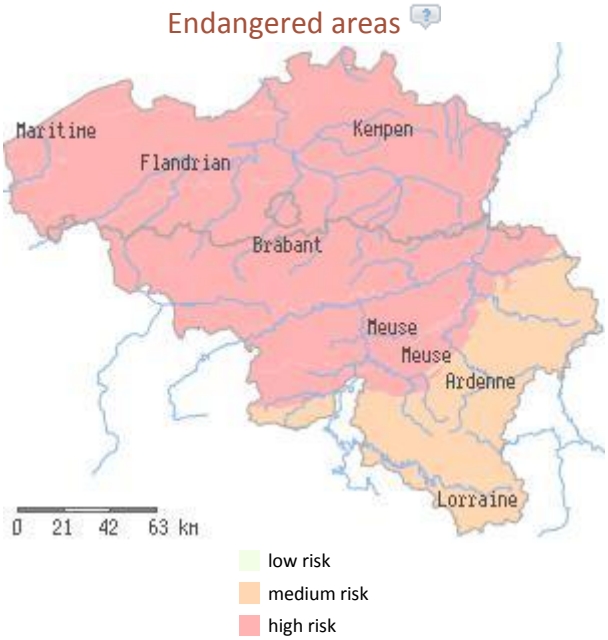
Plant fragments are also easily transported attached to ships or boats. In the Nile river in Egypt, *Myriophyllum* fragments are carried on ships (and other means of river transport), and this is the most likely mechanism for upstream spread of the species in recent years as far as Aswan in Upper Egypt (Springuel and Murphy, 1991). In Canada and elsewhere, quarantine measures have been introduced together with 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.

Finally, the arrival of the plants via natural vectors (especially through waterfowl, either via the digestive tract or attached to plumage) is also a possible means of introduction.

Fig 8. Established population of *Myriophyllum aquaticum,* by geographic district in Belgium. Source: http://ias.biodiversity.be

G/ Endangered areas in Belgium

All humid and wet areas in Belgium (including nature reserves and Natura2000 sites) are potentially suitable habitat for *M. aquaticum* introduction and proliferation. Due to harsh winter conditions, current and predicted future climatic conditions (fide tables in Marbaix P. & J.P. van Yperzele (Eds). 2004 corrected with mean temp 2000-2008 and PRUDENCE approach) should limit *M. aquaticum* establishment to the low and Atlantic parts of Belgium (excluding Ardenne and Lorraine districts).



Establishment capacity in the Belgian geographic districts:

Districts in Belgium	**Environmental conditions for species establishment**[7]
Maritime	Optimal
Flandrian	Optimal
Brabant	Optimal
Kempen	Optimal
Meuse	Optimal
Ardenne	Sub-optimal
Lorraine	Sub-optimal

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

ESTABLISHMENT CAPACITY AND ENDANGERED AREAS IN BELGIUM

M. aquaticum **has been introduced into most continents, and has proved to be highly invasive, especially in the USA, Australia and Southern Europe. Original introductions all appeared to be deliberate, through the use of the species as an ornamental aquarium or pond plant, from where it eventually escaped and spread more or less rapidly by vegetative means. Its continuing use and trade, promotion and availability as an ornamental species means that further introduction to other areas is likely, either of** ***M. aquaticum*** **or of other closely related and potentially invasive species including** ***M. heterophyllum*****.**

Climatic conditions in the lower parts of the country and habitats characteristics of most Belgian fresh water streams and ponds fit within the ecological requirements of ***M. aquaticum*****. Belgium is therefore a place where the species shows a potentially high establishment capacity.** ***M. aquaticum*** **is an aquatic plant and is linked to freshwater habitats. Therefore, most wetlands, streams and ponds (including sensitive areas, nature reserves and Natura2000 sites) are considered vulnerable to invasion. Winter conditions in Ardenne and Lorraine districts should restrict the establishment and the negative impact of the species in those regions.**

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

The spread of plants fragments via natural vectors (especially waterfowl, either via the digestive tract or attached to plumage) is always a possible means of transfer but as male plants are rarely recorded outside the native range, seed production is (so-far) considered negligible as a vector.

B/ Human assistance

Myriophyllum species, like most other invasive aquatic plants, are largely spread between geographically separate regions through human mediated dispersal (mainly by the aquatic plants trade for aquaria and garden ponds (e.g. Revilla et al., 1991; Kay and Hoyle, 2001; Allison, 2003; Gregory, 2003, Halford *et al*., 2004). Once established in a new locality, their spread is 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: e.g Sidorkewicj et al., 2000). Plant fragments are also easily transported attached to ships or boats. In the Nile in Egypt, carriage of *Myriophyllum* fragments on ships and other river traffic is the most likely mechanism for the upstream spread of the species in recent years, as far as Aswan in Upper Egypt (Springuel and Murphy, 1991).

DISPERSAL CAPACITY

Because this is a popular horticultural species, it is often planted in garden ponds, and then discarded accidentally into natural habitats. Once established in a new locality, its spread can happen via a range of mechanisms (most importantly downstream via vegetative fragments). The spread of the plants via natural vectors (especially waterfowl, either via the digestive tract or attached to plumage) is generally considered only a minor vector of propagation.

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 neighboring 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.

Most of the problems have been identified in warmer climate zones than ours. Some specific problems reported for *M. aquaticum* include: interference with fisheries in South Africa (Jacot-Guillarmod, 1979), major problems for hydroelectric power production and forestry development in Argentina (Fernandez et al., 1993), increased incidence of mosquitoes in California (Anderson, 1993).

Myriophyllum aquaticum reduces native species richness at local scales, water quality, habitat quality for fish and wildlife and impacts on human uses (Wersal & Madsen, 2011).

A/ Competition

A study on the impact of three aquatic invasive species, including *M. aquaticum* on native plant and benthic macro-invertebrate assemblages in Belgian ponds (Stiers *et al*., 2009) indicates that a shift from a rather diverse vegetated habitat to a highly homogenous habitat of *M. aquaticum* can present a threat to native plant species and macro-invertebrate abundance, but macro-invertebrate assemblage seems not to be affected.

B/ Predation/herbivory

NA

C/ Genetic effects and hybridization [LIKELY]

No hybridization with other *Myriophyllum* or any genetic effect likely to cause a strong, widespread and persistent decline of the populations of native species are known.

D/ Pathogen pollution

Not to be expected, pathogen pollution is not likely to cause any decline of native species populations and this mechanism is certainly not likely to affect any threatened native species in Belgium.

E/ Effects on ecosystem functions

Worldwide, while *M. aquaticum* may provide cover for some aquatic organisms, it can seriously change physical and chemical characteristics of water bodies. Infestations can alter aquatic ecosystems by shading out algae that serve as the basis of the aquatic food chain. In eutrophic coastal or moderately brackish waters conditions it has been observed to displace native species In addition, the plant provides a preferred mosquito larvae habitat ((EPPO 2004).

ENVIRONMENTAL IMPACTS

Worldwide observed environmental impacts include habitat alteration, modification of hydrology, modification of natural benthic communities, modification of nutrient regime, 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 noted.

In Belgium and in Northern Europe, environmental impacts have not yet been considered as important.

2.2.2 Other impacts

A/ Economic impacts

Because of its attractiveness and ease of cultivation, *M. aquaticum* is a popular aquatic garden plant and is largely commercialized.

But its introduction has also often induced negative costs. In Washington State, the Longview Diking District estimates that it spends US $50.000 a year on *M. aquaticum* control in drainage ditches. A 1985 survey of Californian waters suffering *M. aquaticum* problems (Anderson, 1993) found the direct control expenditure on this weed was US $215.000 over a 2-year period. To put this in perspective, Anderson (1993) estimated the total annual expenditure on aquatic weed control in the western USA to be in the region of US $50 million. Recent estimated costs of Great-Britain wide control for *M. aquaticum* is 1.131.500 £/year (ca 1.360.000€) (Oreska & Aldbridge, 2011).

In California, the species is becoming an increasing problem in irrigation and drainage canals. A 1985 survey of irrigation, mosquito abatement, flood control, and reclamation agencies in California indicated that *M. aquaticum* infested nearly 950 km of waterways and an area of over 200 hectares. In areas where it has become a serious problem, the species is considered to negatively impacts aquaculture/fisheries.

In Belgium, *M.aquaticum* is one of the most regularly encountered invasive species within the plant trade (this plant is sold in 20-25% of nurseries/garden centers both in Belgium and in the Walloon Region). It is even in the top 10 invasive plants most often found in nurseries in the Walloon Region. (Vanderhoeve *et al.* 2006 ; Halford *et al*. 2011).

B/ Social impacts

Dense infestations in southern Africa have caused flooding and drainage problems in shallow rivers and streams. The plant can also restrict recreational opportunities in these water bodies. No such impact have been observed in Belgium yet.

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 should be compared with the natural spread of the organism. Make use e.g. of information used to answer to question 2.1.3.

Intentional and unintentional introduction mediated by human activities (horticultural trade) is the main and probably only significant pathway of introduction.

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.

(i) Prohibition of organism importation, trade and holding

Its availability in plant nurseries should be regulated or even forbidden. 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 all 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.

In Belgium (and other non-native countries of the species) several actions can be undertaken in order to limit introduction of *Myriophyllum aquaticum*:

- **Action 1: Amend existing legislation.**

Legislation should be strengthened to ensure a total ban on import and possession of potential invasive plants such as *M. aquaticum* and closely related species.

- **Action 2: Highlight, support and promote Invasive Species Codes of Practice.**

A priority action to prevent the spread and release of invasive species such as *M. aquaticum* is to promote wide use and implementation of the Invasive Species Codes of Practice (ISCP; Table below), recently developed in Belgium through the AlterIAS LIFE project (http://www.alterias.be), and to support these with literature and information leaflets for both the horticultural sector and the general public (see table 1).

Table 1: Invasive Species Codes of Practice for the industry and the general public.
Source: http://www.alterias.be/fr/que-pouvons-nous-faire/les-codes-de-conduite-sur-les-plantes-invasives

ISCP for horticultural professionals	**ISCP for the general public**
1.Be informed about the Belgian alien species list	1.Be informed about the Belgian alien species list
2.Stop selling and/or planting invasive alien species	2.Avoid buying and planting alien species
3.Spread information about invasive alien species to customers and the general public	3.Choose non-invasive native plants as an alternative to alien species
4. Promote the use of alternative, non-invasive plants	4.Do not dump vegetal residues in nature
5. Take part in early invasive alien species detection actions	5. Share your knowledge and awareness about invasive plants and issues related to their introduction

Indeed, *M. myriophyllum* is valued as an ornamental plant, therefore educational programs must be directed to educate the public about the dangers this plant poses outside its native range. Teaching water managers how to clean equipment in a way that decreases the chance of transmission is one way to lessen the prevalence of human-mediated transport. Additionally, information should be disseminated regarding responsible propagation and cultivation of this species if it remains to be sold (which is an undesired scenario).

In Belgium, a large information campaign was already promoted by AlterIAS. Such initiatives enhance awareness of the risks caused by invasive species, facilitate early warning and correct identification and provide valuable measures for careful culture and manipulation, as well as trade reduction, by proposing alternative garden plants through detailed Invasive Species Codes of Practice, targeting the public at large as well as retailers. As the species is still easily available in Belgium (see para 2.2.2.), there is an opportunity for education at various points along the horticultural trade pathway from distributor to introduction.

- **Action 3: Public sector bodies adopt Invasive Species Codes of Practice**

All public sector organizations should lead by example and adopt the Invasive Species Codes of Practice in their relevant work areas. This is key to the success of both existing codes (for professionals in horticulture and for general public). Government agencies should also incorporate the philosophy of the codes into tenders and procurement procedures and ensure that suppliers and contractors for public works are abiding the codes.

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

Should not be released in the wild. Dispose of garden and pond waste responsibly. Check vehicles, boats, equipment and clothing for plant fragments when leaving infested sites and clean if necessary.

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.

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)?

Identification is easy, as glaucous foliaged *Myriophyllum aquaticum* emergent stems standing up to 30 cm or more above the water surface cannot be confused with any other species of its genus, so the species can easily be detected at an early stage of invasion. The presence of emergent stems (even in the non-flowering phase) is a good identification feature, distinguishing *M. aquaticum* from most of the related species, with the exception of the other potentially invasive *M. heterophyllum*.

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

The side effect of chemicals, mechanical 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.

- **Environmental Control**

Reducing nutrients, especially nitrogen is likely to reduce the vigour of this species, the critical value being approximately 1.8mg/L N below which the species is stunted (Sytsma & Anderson, 1993d). Reducing water column phosphate does not appear to limit growth.

Reducing light will decrease the net photosynthetic gain by the plant, and observations show that growth is severely limited by even low levels of shade.

There is some evidence to suggest that *M. aquaticum* does not grow well in water deeper than 50 cm, especially if the adventitious roots cannot come into contact with the sediment surface to enable enhanced nutrient uptake (Sytsma & Anderson, 1993b,1993c).

Deepening channels or the margins of lakes and ponds may reduce regrowth once other control activities have taken place.

- **Mechanical control**

Because *M. aquaticum* can spread readily through fragmentation of rhizomes, mechanical controls such as cutting, harvesting, and rotovation (underwater rototilling) should be used only when the extent of the infestation is such that all suitable space has been filled. Using mechanical controls while the plant is still invading, will tend to enhance its rate of spread.

Parrot feather mechanical cutting is rarely effective (Jacot-Guillarmod, 1977), it can be successfully harvested, but the dense tough rhizomes are very heavy and the plant will regrow rapidly from shoot

fragments. However, more effective harvesting systems that remove the biomass and accumulated nutrient reserves may offer control possibilities (Sytsma and Anderson, 1993).

Small, recently detected infestations may be successfully eradicated through careful and thorough hand-pulling or using a tarpaulin. For small ponds and if a long term drying-out is feasible, Delbart E., A. Monty & G. Mahy (2012) propose:

- a complete dry-out of the ponds for a minimum period of 9 months;
- or a combination of a shorter dry-out period (including chemical treatment time + 2 weeks) with a chemical treatment (glyphosate1) and a complementary careful yearly hand-pulling extended over two years.

If the population of *M. aquaticum* is limited, the plants superficially rooted and the ground soft (muddy ground) :

- careful hand-pulling, with repetition one or several time during the first years after eradication.

- **Chemical control**

M. aquaticum is highly susceptible to 2,4-D, in spray or granular formulations (Blackburn and Weldon, 1963; Braddock, 1966) and this treatment is most effective when applied to young, actively-growing plants (Sutton and Bingham, 1970). Also effective are simazine, copper (Sutton et al., 1969; Sutton and Blackburn, 1971), endothal and dichlobenil (Mixon, 1974). Glufosinate ammonium and 2,4-D amine were more effective than diquat and glyphosate in Portugal (Monteiro and Moreira, 1990).

- **Biological control**

There are no specific bio-control agents known. Cattle and waterfowl graze the shoots, but standard bio-control fish such as grass carp (*Ctenopharyngodon idella*) were found to dislike *M. aquaticum* in Portugal and in the USA (Pine and Anderson, 1991), possibly due to high levels of tannin. The insects *Lysathia flavipes* and *Listronotus marginicollis* attack *M. aquaticum* in its native range in Argentina (Habeck and Wilkerson, 1980), *Parapoynx allionealis* larvae mine the leaves and *Lysathia ludoviciana* and *Pythium carolinianaum* attack stems in the USA (Bernhardt and Duniway, 1984). However, it is rare to observe *M. aquaticum* in other than vigorous health, suggesting a high degree of natural resistance to pests and diseases. Verma and Charudattan (1993) reported that *Mycoleptodiscus terrestris* formulated as a mycoherbicide in alginate beads showed some toxicity to *M. aquaticum*.

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

Physical removing, drying-out, shading and herbicide treatments, though sometimes effective to control *M. aquaticum,* are non-specific means of control. 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 services alteration. These side effects could indeed drastically affect native species.

Attempts to control *M. aquaticum* invasion by biological means (e.g. introduction of the exotic grass carp) can negatively impact the native submerged vegetation and aquatic fauna.

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

There are no efficient herbicides available for the control of this species. Mechanical control will encourage dispersal, spread and establishment to new areas. Efficient biological control is not yet established. Mechanical control associated with harvesting may be an appropriate option for (small) sites at a very early stage of invasion. Several successes have been documented (Veraart & Soens 2010; Delbart *et al.* 2012; Monty *et al*. 2013).

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

In sub-optimal climatic conditions (like in the Ardenne and Lorraine districts) probably yes. Unlikely in other parts of Belgium.

BEST MANAGEMENT MEASURES

Since chemical weed control in an aquatic environment is extremely restricted in Belgium and its different regions and because the results should be of practical use, the practical control options should focus on prevention and non-chemical methods.

Effective management of this species for eradication is relatively difficult. Mechanical control tends to remove very large amounts of material in a relatively short period of time, but due to the rapid regeneration of fragments of leaves, shoots and roots, recolonisation is inevitable within weeks. Small, recently detected infestations may be successfully eradicated through careful and thorough hand-pulling or using a tarpaulin. Continuous efforts should be made to remove plants as soon as they reappear after mechanical control to prevent re-infestation and dominance of the habitat.

Its availability in plant nurseries should be regulated or even forbidden. A trading ban for *Myriophyllum aquaticum* (and all other highly invasive non-indigenous aquatic plants) should reduce the risk of further unintended entry and thus can be a major control factor even if this will not stop natural spread,

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