museum
www.naturalsciences.be

federal public service
HEALTH, FOOD CHAIN SAFETY
AND ENVIRONMENT

© Jo Packet

Risk analysis of the Brazilian Waterweed, *Egeria densa* Planch.

Risk analysis report of non-native organisms in Belgium

Developed by :
René-Marie Lafontaine
Roseline C. Beudels-Jamar
Henri Robert
Thibaut Delsinne

Adopted in date of : 11 March 2013

Risk analysis report of non-native organisms in Belgium

Risk analysis of the Brazilian Waterweed *Egeria densa* Planch.

René-Marie Lafontaine – Roseline C. Beudels-Jamar – Henri Robert – Thibaut Delsinne

Royal Belgian Institute of Natural Sciences ; OD Natural Environment ; Conservation Biology Team ; Rue Vautier 29, 1000 Brussels ; http://www.sciencesnaturelles.be

Reviewed by : Luc Denys (INBO)

Adopted in date of: 11th March 2013

Commissioned by: Federal Public Service Health, Food chain safety and Environment

Contact person: Rene-Marie.Lafontaine@naturalsciences.be

This report should be cited as:
Lafontaine, R.-M., Beudels-Jamar, R.C., Robert, H., Delsinne, T. (2013). Risk analysis of the Brazilian Waterweed *Egeria densa* Planch. - 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. 36 p.

Contents

Acknowledgements 2
Rationale and scope of the Belgian risk analysis scheme 3
Executive summary 5
Résumé 7
Samenvatting 9

STAGE 1: INITIATION 11
1.1 ORGANISM IDENTITY 11
1.2 SHORT DESCRIPTION 11
1.3 ORGANISM DISTRIBUTION 13
1.4 REASONS FOR PERFORMING RISK ANALYSIS 14

STAGE 2 : RISK ASSESSMENT 15
2.1 PROBABILITY OF ESTABLISHMENT AND SPREAD (EXPOSURE) 15
2.1.1 Present status in Belgium 15
2.1.2 Present status in neighbouring countries 16
2.1.3 Introduction in Belgium 19
2.1.4 Establishment capacity and endangered area 25
2.1.5 Dispersion capacity 26
2.2 EFFECTS OF ESTABLISHMENT 27
2.2.1 Environmental impacts 27
2.2.2 Other impacts 29

STAGE 3 : RISK MANAGEMENT 30
3.1 RELATIVE IMPORTANCE OF PATHWAYS FOR INVASIVE SPECIES ENTRY IN BELGIUM 30
3.2 PREVENTIVE ACTIONS 30
3.3 CONTROL AND ERADICATION ACTIONS 31

LIST OF REFERENCES 34

Acknowledgements

The authors wish to thank the reviewers who contributed to this risk analysis with valuable comments and additional references: Luc Denys (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)
Roseline Beudels-Jamar	Royal Belgian Institute of Natural Sciences (RBINS/KBIN)
Etienne Branquart	Département de l'Etude du Milieu Naturel et Agricole (DEMNA)
Jim Casaer	Research Institute for Nature and Forest (INBO)
Thibaut Delsinne	Royal Belgian Institute of Natural Sciences (RBINS/KBIN)
Maud Istasse (chair)	Federal Public Service Health, Food chain safety and Environment
René-Marie Lafontaine	Royal Belgian Institute of Natural Sciences (RBINS/KBIN)
Alice Lejeune	Federal Public Service Health, Food chain safety and Environment
Céline Prévot	Département de l'Etude du Milieu Naturel et Agricole (DEMNA)
Henri Robert	Royal Belgian Institute of Natural Sciences (RBINS/KBIN)
Vinciane Schockert	Université de Liège (ULg)
Sonia Vanderhoeven	Belgian Biodiversity Platform (BBPF)
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 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)

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).

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):

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

Photo : Kristian Peters ; Source : Wikimedia commons.

Executive summary

PROBABILITY OF ESTABLISHMENT AND SPREAD (EXPOSURE)

- Entry in Belgium

Egeria densa is a popular aquarium plant that was first reported in the wild in Belgium in 1999. The principal pathway of introduction is the disposal of aquaria contents into local waterways. Further dissemination in natural habitats occurs through the spread of vegetative propagules. Many introduced populations comprise only male plants; seed formation has not been observed. Further introduction and spread are likely to continue.

- Establishment capacity

Egeria densa has a very wide ecological amplitude. It thrives in various types of freshwater habitats, from acidic to alkaline and varying trophic status. It prefers slow flowing waters but may also be found in still waters. This aquatic weed is light demanding but still able to develop in deep and turbid water. Habitat characteristics of most Belgian freshwater habitats are within the ecological requirements of *Egeria densa*. Belgium is therefore a country where the species shows a high probability of establishment.

At present the species does not show very effective natural spreading, this is probably due to its sensitivity to freezing in winter. With the expected rise in temperature due to climate change and being essentially a freshwater opportunist, most wetlands, streams and ponds, including sensitive areas, nature reserves and Natura2000 sites, except the Ardenne (and possibly Lorraine) district(s), are considered vulnerable to invasion by *E. densa*.

- Dispersion capacity

Human activities can greatly enhance dispersal if precautions are lacking. The species capacity to colonize remote areas is clearly linked to human assistance, mainly through trade and disposal of aquaria contents into local waterways. In the non-native range, short distance dispersal by vegetative means is facilitated by weed cutting and other river management, by boating or by accidental transport on human clothes, footwear, and fishing equipment. Widespread establishment is more likely to occur in waterways and standing waters within the floodplain of infected streams.

EFFECT OF ESTABLISHMENT

- Environmental impacts

In areas of significant infestation (such as the USA or Australia) *Egeria densa* is reputed to disrupt natural erosion-deposition processes, disrupt the movement of animals, out-compete native aquatic plants, limit light availability to other plants, disrupt predator-prey relationships, prevent wind mixing, cause local oxygen depletion, create mosquito breeding areas and increase water temperature by absorbing sunlight, while die back can increase nutrient loads to the water. None of these impacts have been observed in Belgium yet but could occur if populations might increase significantly.

RISK MANAGEMENT

The main current pathway of introductions of *Egeria densa* in Belgium remains its sale as an ornamental plant for aquariums and ponds, and its subsequent release in the wild. This pathway is however expected to decrease thanks to awareness campaigns (e.g. in the framework of the AlterIAS LIFE project). Once established, vegetative dispersal through vegetative propagule is expected.

Legislation at European level to ensure a total ban on import, trade and cultivation of *Egeria densa* and other (potentially) invasive aquatic plants is likely to be most effective. Fortunately, *E. densa* is still at an early stage of invasion in Belgium and is restricted to small isolated areas. As a result, similar national regulation could effectively prevent its entry, establishment and spread.

Egeria densa is difficult to detect at an early stage of invasion, and therefore control or eradication action often starts when the plant is already well-established.

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 (mechanical removal in the case of *Egeria densa*).

Résumé

PROBABILITE D'ETABLISSEMENT ET DE DIFFUSION (EXPOSITION)

- Introduction en Belgique

Egeria densa est une plante d'aquarium populaire dont la présence à l'état sauvage a été rapportée pour la première fois en Belgique en 1999. Sa principale voie d'introduction est l'élimination des eaux des aquariums (et déchets végétaux) dans les cours d'eau locaux. Sa dissémination ultérieure dans les habitats naturels s'effectue ensuite par la dispersion des propagules végétatives. Au vu du caractère invasif de l'espèce et de sa capacité d'établissement, il est raisonnable de penser que son introduction et sa dissémination vont très certainement se poursuivre sur notre territoire.

- Capacité d'établissement

Egeria densa présente une très large amplitude de tolérance écologique. Elle se développe abondamment dans différents types d'habitats d'eau douce (même s'ils sont acides ou eutrophes). Elle montre cependant une préférence pour les eaux à débit lent mais on la trouve aussi dans les eaux stagnantes. Cette plante, essentiellement aquatique, a besoin de lumière mais est capable de se développer dans des eaux profondes et troubles. Les caractéristiques de la majorité des cours d'eau belges répondent aux besoins écologiques d'*Egeria densa.* La Belgique est donc un pays dans lequel l'espèce montre une forte probabilité d'établissement.

La dissémination naturelle de l'espèce en Belgique est, pour l'instant, relativement limitée à cause de sa sensibilité au gel hivernal. Etant donné que l'on s'attend à une élévation de la température due aux changements climatiques et que cette espèce est essentiellement une espèce opportuniste des eaux douces, la majorité des zones humides, cours d'eau et étangs, y compris les zones sensibles, les réserves naturelles et les sites Natura 2000, (à l'exception de ces habitats présents en Ardenne et peut-être aussi en Lorraine) sont considérés comme étant vulnérables à l'envahissement par *E. densa.*

- Capacité de dispersion

Les activités humaines et le manque de précautions peuvent grandement favoriser la dispersion d'*E. densa* dans l'environnement. La capacité de l'espèce à coloniser des zones fort distantes de populations existantes est clairement liée à l'activité humaine, principalement par le biais du commerce et de l'élimination du contenu des aquariums dans les cours d'eau locaux. A courte distance (et en dehors de son aire de répartition originelle), sa dispersion par voie végétative est facilitée par le désherbage et les mesures de gestion des cours d'eau, par le transport sur les voies navigables ou le transport accidentel sur les vêtements, les chaussures ou sur le matériel de pêche. Un établissement à grande échelle est d'autant plus probable si les cours d'eau ou eaux stagnantes infestés se situent en plaines inondables.

EFFET DE L'ETABLISSEMENT

- Impacts environnementaux

Dans les zones d'envahissement (notamment aux Etats-Unis et en Australie), *Egeria densa* perturbe les processus naturels d'érosion et de sédimentation. Elle limite la mobilité de la faune, supplante les plantes aquatiques indigènes, limite la pénétration de la lumière dans la colonne d'eau, perturbe les

relations proies-prédateurs, empêche le brassage des eaux stagnantes par le vent, provoque une diminution de la concentration en oxygène dans l'eau, crée des zones favorables à la reproduction des moustiques, augmente la température de l'eau et augmente l'apport en nutriments dans l'eau (eutrophisation). Aucun de ces impacts n'a encore été observé en Belgique mais ce pourrait être le cas si les populations de cette espèce devaient fortement augmenter.

GESTION DES RISQUES

La principale voie d'introduction actuelle d'*Egeria densa* en Belgique reste sa vente en qualité de plante ornementale pour les aquariums et les étangs et son rejet subséquent dans la nature. On peut toutefois s'attendre à ce que les cas d'introduction par négligence dans le milieu naturel diminuent grâce à des campagnes de sensibilisation (p. ex. dans le cadre du projet AlterIAS LIFE). Une fois *Egeria densa* établie, on s'attend à ce qu'une dispersion végétale s'opère via les propagules.

Une législation cohérente au niveau européen destinée à assurer l'interdiction totale d'importer, vendre ou cultiver l'*Egeria densa* (et d'autres plantes aquatiques potentiellement envahissantes) est considérée comme le moyen le plus efficace pour lutter contre l'envahissement par cette espèce.

E. densa est encore à un stade d'envahissement très précoce en Belgique et les populations connues restent limitées à de petites zones isolées. Par conséquent, une réglementation nationale similaire pourrait efficacement prévenir son introduction, son établissement et sa dissémination.

Egeria densa est difficile à détecter à un stade précoce d'envahissement. Pour cette raison, les actions de contrôle ou d'éradication ne sont souvent mises en place que quand la plante est déjà bien établie.

Etant donné que la lutte chimique contre les mauvaises herbes dans l'environnement aquatique est extrêmement réglementée 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 non chimiques (arrachage mécanique dans le cas de l'*Egeria densa)*.

Samenvatting

WAARSCHIJNLIJKHEID VAN VESTIGING EN VERSPREIDING (BLOOTSTELLING)

- Ingang in België

Egeria densa is een populaire aquariumplant die voor het eerst in 1999 in België in het wild werd opgemerkt. De voornaamste introductieweg is het lozen van de inhoud van aquaria in waterlopen. De verdere verbreiding in natuurlijke habitats gebeurt via de verspreiding van vegetatieve delen. Vele geïntroduceerde populaties bestaan enkel uit mannelijke planten; er werd geen zaadvorming waargenomen. Verdere introductie en verspreiding zijn erg waarschijnlijk.

- Vestigingsvermogen

Egeria densa heeft een heel ruime ecologische amplitude. De soort gedijt in verschillende soorten zoetwaterhabitats, gaande van zuur tot alkalisch water met een uiteenlopende voedselrijkdom. Ze verkiest traag stromend water, maar wordt ook in stilstaand water aangetroffen. Hoewel dit aquatisch onkruid veel licht verlangt, groeit het ook in diep en troebel water. De meeste Belgische zoetwaterhabitats vallen binnen het ecologische bereik *Egeria densa*. Daarom is de waarschijnlijkheid van vestiging in België heel hoog.

Momenteel vertoont de soort geen erg effectieve natuurlijke verspreiding, wat vermoedelijk te maken heeft met de vorstgevoeligheid. Met de verwachte stijging van de temperatuur door klimaatverandering en omdat het een zoetwateropportunist betreft, worden de meeste waterrijke gebieden, met inbegrip van kwetsbare gebieden, natuurgebieden en Natura2000 gebieden met waterlopen en vijvers, uitgezonderd deze in de Ardennen (en mogelijk Lotharingen) beschouwd als kwetsbaar voor invasie met *E. densa*.

- Verspreidingsvermogen

Bij het uitblijven van voorzorgen kunnen menselijke activiteiten de verspreiding sterk in de hand werken. Het vermogen van de soort om afgelegen gebieden te koloniseren hangt duidelijk samen met menselijke hulp, vooral door handel en het al dan niet opzettelijk verspreiden in oppervlaktewateren. In het niet-inheemse bereik wordt de verspreiding over korte afstand via vegetatieve weg in de hand gewerkt door het maaien van waterplanten en ander rivierbeheer, door scheepvaart, of door onopzettelijk transport op kledij en schoeisel, visgerei, enz. Grootschalige vestiging zal zich veeleer voordoen in waterlopen en stilstaand water in het overstromingsgebied van waterlopen waarin de soort aanwezig is.

EFFECTEN VAN DE VESTIGING

- Milieu-impact

In sterk besmette gebieden (zoals de VS of Australië) leidt uitbundige ontwikkeling van *Egeria densa* tot verstoring van de natuurlijke erosie-depositieprocessen, verminderde bewegingsvrijheid voor sommige dieren, het verdringen van inheemse waterplanten, beperking van de lichtbeschikbaarheid voor andere planten, wijziging van predator/prooi-relaties, verminderde waterturbulentie, plaatselijk zuurstofgebrek en stijging van de watertemperatuur. Het afsterven van grote hoeveelheden planten

kan de hoeveelheid nutriënten in het water doen toenemen. Het broedsucces van muggen kan toenemen. In België werd tot dusver nog geen enkele van deze gevolgen waargenomen, maar deze zullen wellicht niet uitblijven indien de soort algemener wordt en grote bestanden kan vormen.

RISICOBEHEER

De voornaamste actuele introductiewegen van *Egeria densa* in België blijven de verkoop als sierplant voor aquaria en vijvers en het vervolgens uitplanten of wegwerpen ervan in het wild. Verwacht wordt dat bewustmakingscampagnes (v.b. in het kader van het AlterIAS LIFE project) dit kunnen verminderen. Eens gevestigd wordt vegetatieve verspreiding door vegetatieve propagulen verwacht, bijzonder in waterlopen.

Het meeste heil kan worden verwacht van een wetgeving op Europees niveau die de invoer, handel en het cultiveren van *Egeria densa* en andere (potentieel) invasieve waterplanten zal verbieden. Gelukkig is de invasie van de *E. densa* in België nog in een vroeg stadium en beperkt tot kleine, geïsoleerde gebieden. Dit betekent dat gelijkaardige regelgeving op nationaal niveau de introductie, vestiging en verspreiding doeltreffend kan verhinderen.

Egeria densa is in een vroeg invasiestadium moeilijk op te sporen; daarom starten de controle- of uitroeiingsacties vaak pas als de plant al goed is gevestigd.

Omdat chemische onkruidbestrijding in een aquatisch milieu in België aan verregaande beperkingen is onderworpen en omwille van de erg schadelijke effecten ervan op de biodiversiteit, het milieu in ruime betekenis en de volksgezondheid, zijn preventie en niet-chemische methoden (i.c. mechanisch verwijderen) in de praktijk de voornaamste controleopties.

STAGE 1: INITIATION

1.1 ORGANISM IDENTITY

Scientific name : *Egeria densa* Planch.

Synonyms: *Anacharis densa* (Planch.) Vict.
Elodea densa (Planch.) Casp.
Philotria densa (Planch.) Small & St. John

Common names : Brazilian Elodea, Brazilian Waterweed, Common Waterweed, Dense Waterweed, Egeria, Large-flowered Waterweed, Leafy Elodea, South American Waterweed (Eng); Égéria, Élodée dense (Fr); Egeria (Nl); Dichte Wasserpest, Dichtblättrige Wasserpest (Ge); Elodea, Maleza Acuática brasileña (Sp).

Taxonomic position: Domain: Eukaryota / Kingdom: Plantae / Phylum: Spermatophyta / Subphylum: Angiospermae / Class: Liliopsida / Order: Hydrocharitales / Family: Hydrocharitaceae / Genus: *Egeria* / Species: *Egeria densa.*

1.2 SHORT DESCRIPTION

A description of *Egeria densa* is availbale on the Invasive Species Compendium website (ISC, 2012): *"Egeria densa* is a herbaceous, tender plant, with cauline leaves regularly disposed in close whorls, resembling cylinders 2-6 cm thick and 10-90 cm long [Figures 1 & 2]. Stems sparsely branched, with short internodes, delicate, breaking easily with the parts forming new plants. In shallow water, plants can be anchored to the bottom, otherwise free-floating. Filament-like roots, at the base of plants and at some nodes, especially in broken pieces. Leaves sessile, lanceolate, 1-3 cm long and 5 mm large, apex rounded or acute, margins finely serrated, surface smooth, intensely green when receiving natural light, more pale in aquaria. *E. densa* normally presents four leaves per whorl, but can present five or six. Plants are dioecious [meaning that male and female flowers are on different plants. In its introduced range, only males were recorded so far (Toussaint & Bedouet, 2005)]. From the axils of some leaves arise spathes and from their interior emerge floral peduncles 2-6 cm long, that expose solitary flowers ca. 2 cm above the water surface. Male flowers are in groups of 2-4, from one spathe, the perianth formed by a calyx of 3 green sepals, corolas with 3 white petals, 10-15 mm long, stamens 9. Female flowers one per spathe, perianth like that of males, ovary unilocular formed by 3 carpels, androecium only residual with 3 yellow staminodes. Fruits are berry-like, ovate, 7-8 mm long and 3 mm wide with membranaceous and transparent pericarp. Seeds numerous, fusiform, 7-8 mm long, with a 2 mm filament present at the end." For additional details, see the more complete and well-illustrated description of the species by Cook & Urmi-König (1984).

Several other Hydrocharitaceae are now present in European waters and could be confused with *Egeria densa* (Figure 2). Historically the genera *Elodea, Egeria, Hydrilla* and *Lagarosiphon* have been much confused in the literature, mainly because of similarities in appearance and habitats. They are all submersed water plants, with leaves usually in whorls of two to eight. The number of leaves in a whorl is an important vegetative diagnostic feature, but there is a large overlap between genera (Nienhuis, 2008). An identification key to the species level is given by Rose (2006) for all the species more likely

to be found in the wild in our study area. Along with *Egeria densa*, the introduced *Lagarosiphon major*, *Elodea canadensis*, and *Elodea nuttallii* are keyed. All these plants are black listed in Belgium (Branquart, 2012).

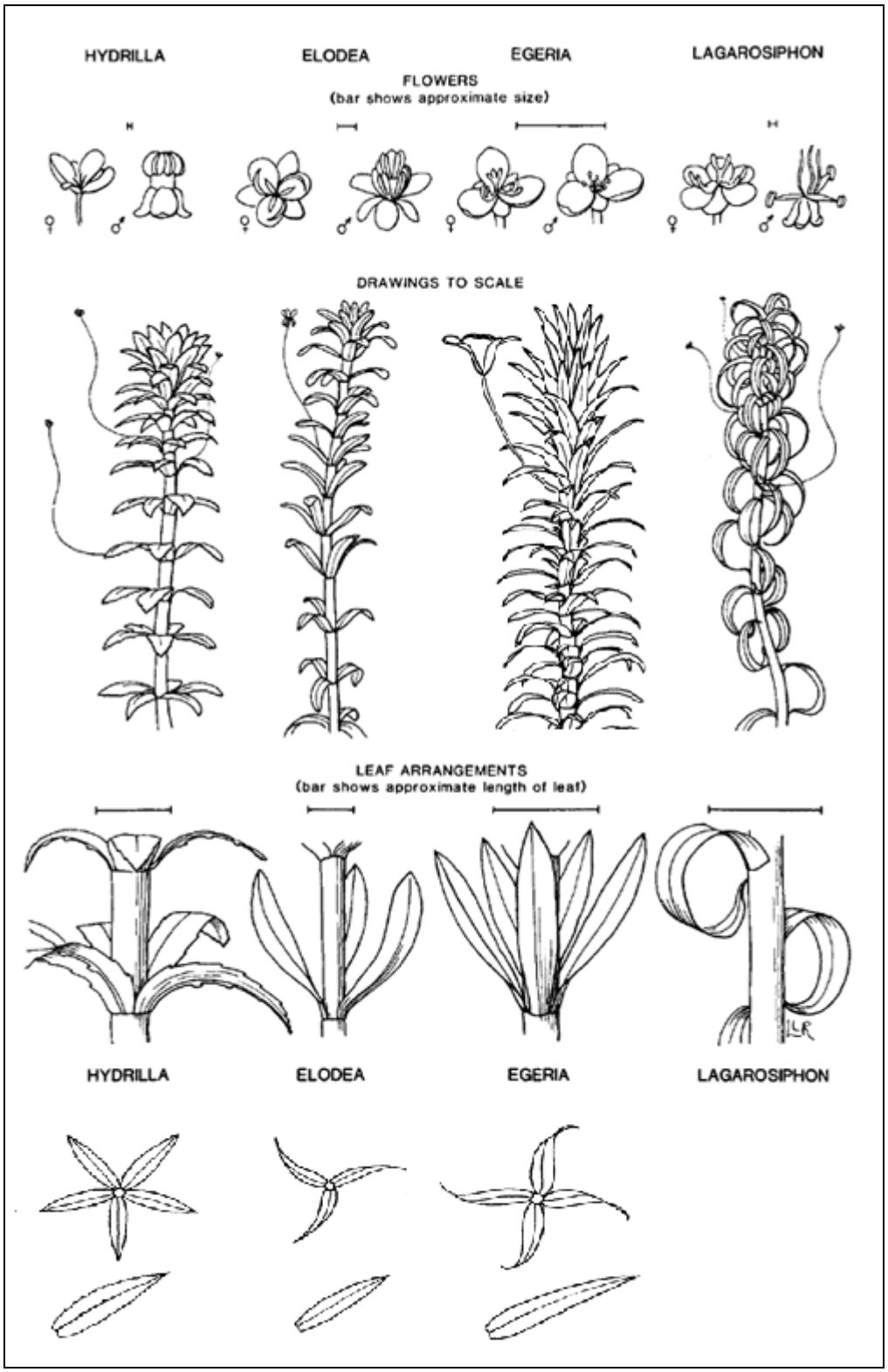

Figure 2: Morphologically similar-looking Hydrocharitaceae genera. Leaves of *Lagarosiphon* sp. are spirally arranged along the stem, whereas leaves of the other genera are in whorls of 3-5 leaves. Size of leaves and flowers, and average number of leaves per whorl are key criteria to separate *Egeria* from

Elodea and *Hydrilla* [*H. verticillata* is a native species rare and sparsely distributed in Europe (UK, Germany, Baltic States)] (Rose, 2006). Modified from IFAS, 2013.

1.3 ORGANISM DISTRIBUTION

Native range

Egeria densa is native to temperate Atlantic zone and subtropical parts of Argentina, Brazil and Uruguay (Yarrow et al., 2009), more precisely, the original distribution of *Egeria densa* ranged from the central Minas Gerais region of Brazil to the coastal areas of Uruguay and Argentina (Figure 3). It is common in the Paraná basin of Argentina (Yarrow et al., 2009).

Introduced range

Being one of the most common plants for aquaria (Winterton & Scher, 2007) and often used for biochemical and physiological investigations, *Egeria densa* has been widely distributed around the world. In many regions it has escaped and male plants are recorded in natural habitats in Europe, East and South Africa, Japan, Australia, New Zealand and North and Central America (ISSG, 2006; Duggan, 2011; ISC, 2012).

Belgium: *Egeria densa* is now fully naturalised in a few locations in Flanders (Denys et al., 2004). The species penetrates in semi-natural habitats, for instance in the valley of the Kleine Nete and Dommelvallei (Peer) and could locally become invasive (Manual of the Alien Plants of Belgium, http://alienplantsbelgium.be [accessed 12-02-2013]).

Rest of Europe: Austria, Portugal (Azores), France, Germany, Denmark?, Italy, the Netherlands, Switzerland and the UK.

Other continents: Africa (Kenya, Algeria), Asia (Japan; and Bangladesh recently (Alfasane et al. (2010)), Australia, New Zealand, North America (USA, Canada, Mexico), part of South America (Colombia, Chile).

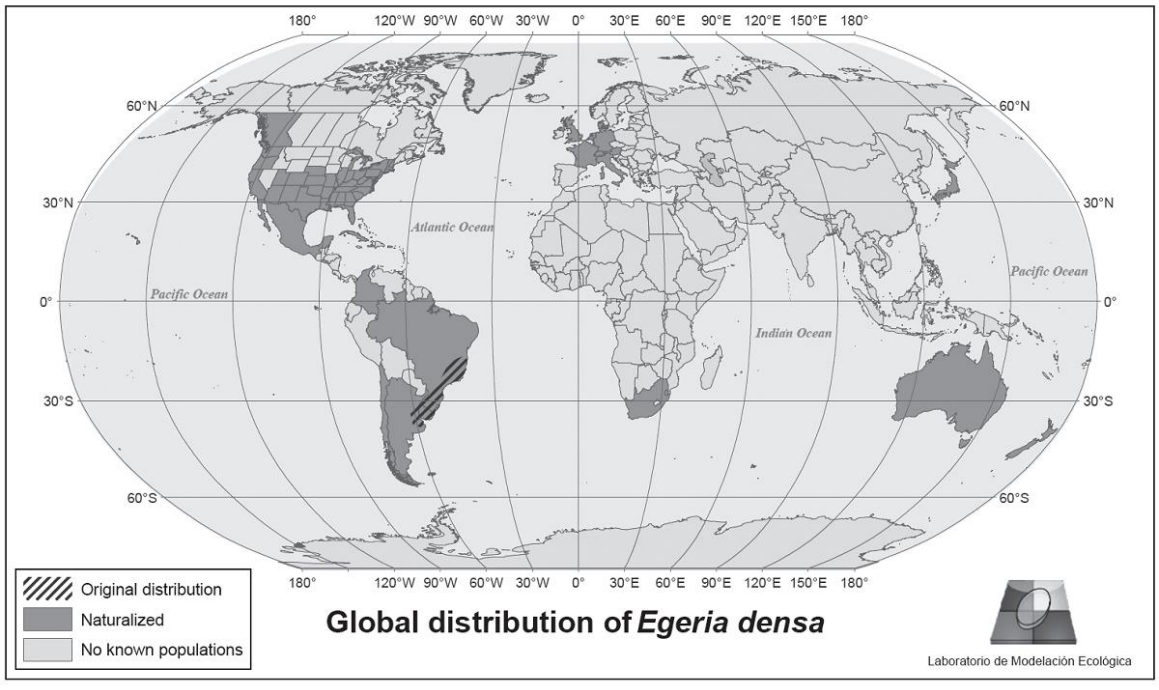

Figure 3: World distribution of *Egeria densa* (from Yarrow et al., 2009).

1.4 REASONS FOR PERFORMING RISK ANALYSIS

Egeria densa has a very wide ecological amplitude. It thrives in various types of freshwater habitats, from acid to eutrophic environments. It prefers flowing systems but may also be found in still waters. This aquatic weed is not light demanding and is able to develop in deep and turbid waters. In many areas it is not invasive, however it is a serious problem in parts of the United States and Australia.

As Branquart et al. (2010) explain: "*Egeria densa* is highly competitive in meso-eutrophic waters. As observed for most non-native Hydrocharitaceae species, this submerged perennial aquatic plant makes dense mono-specific populations which often colonize entire water bodies, restrict water movement, cut off light, produce anoxic conditions and trap sediments in the system. The Brazilian waterweed has been reported to outcompete native aquatic plants and to adversely affect fish communities. Dense beds provide a poor habitat for aquatic animals and are generally not consumed by fish. They interfere with recreation activities and increase the risk of adjacent land flooding."

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.

Egeria densa is a rare escape from the aquarium and pond trade (Figure 4). The species was reported for the first time in 1999 in a small pond in Ezemaal, Brabant (Robijns et al., 2002). Since then the number of records has increased and the species is now considered fully naturalized at a few locations in Flanders, mainly within the basin of the River Nete (Denys et al., 2004; Figure 5). Up to present the species was recorded at only one site in Wallonia, Magombroux near Verviers in 2009 (DEMNA Database, January 2013).

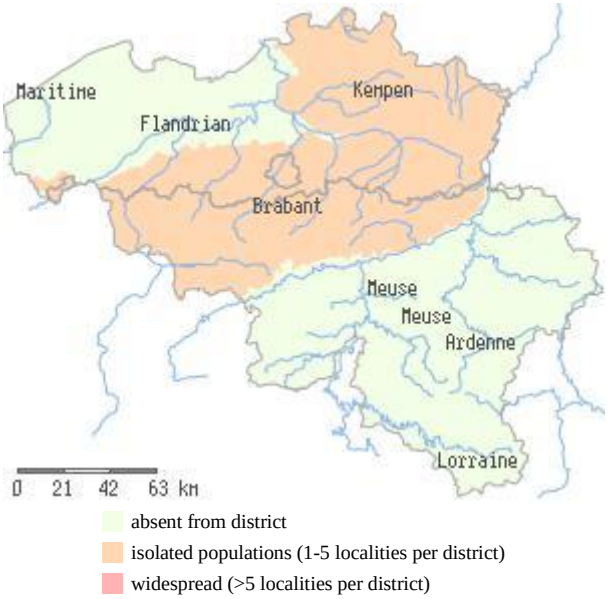

Figure 4: Indicative number of established populations of *Egeria densa* by geographic district in Belgium. Source: http://ias.biodiversity.be

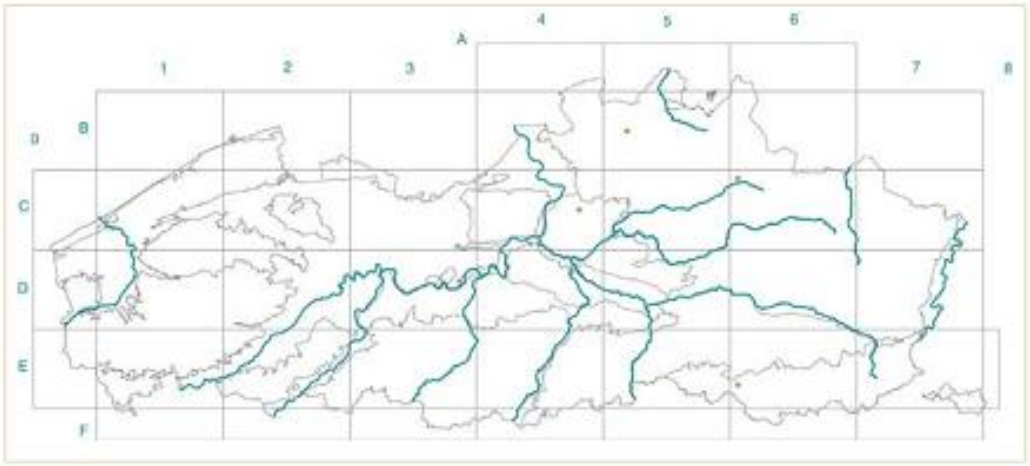

Figure 5: Distribution of *Egeria densa* in Flanders in 2004 (from Denys *et al.*, 2004).

2.1.2 Present status in neighbouring countries

Mention here the status of the non-native organism in the neighbouring countries.

- **The Netherlands:**

Egeria densa was first recorded in 1944 near Dordrecht (Cook & Urmi-König, 1984). The species is now relatively widespread (ca. 25 localities) in the Netherlands with isolated and localized populations in some waterways and public ponds (Figure 6).

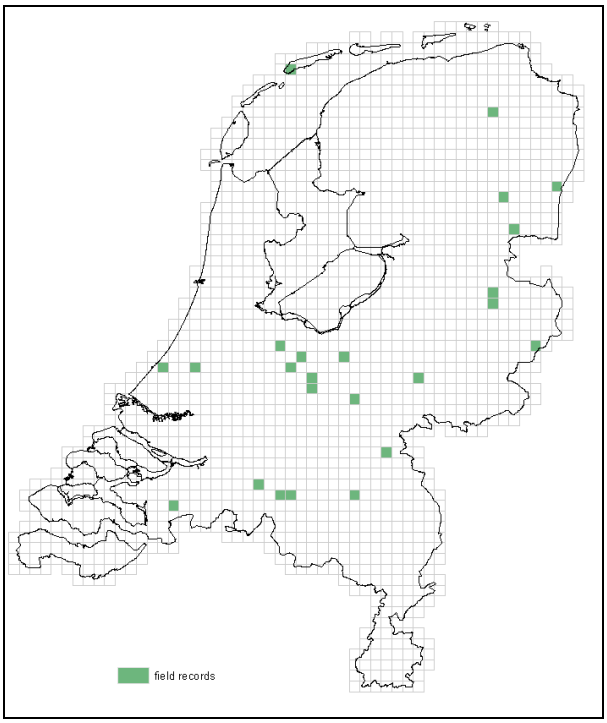

Figure 6: Distribution of *Egeria densa* in the Netherlands (Source: http://www.q-bank.eu; accessed 15-12-2012).

- **France:**

Egeria densa has been in cultivation in France since at least 1919 (St. John, 1961). The species was first discovered in the wild in 1960 in the Manche department (Feuillade, 1961a, 1961b; Thiébaut, 2007) and has then spread along the entire Atlantic coast (Dutarte et al., 1999). It is now relatively widespread and spreading in France, mainly in Bretagne, Pays-de-Loire, Centre, Ile-de-France, Limousin, Midi-Pyrénées, Auvergne and Rhône-Alpes (Figure 7) but it is not yet considered as an invasive (Muller, 2004; Thiébaut, 2007; Toussaint & Bedouet, 2005). According to Cook & Urmi-König (1984), *Egeria densa* is naturalized since 1940 in Martinique and Guadeloupe (West Indies). In the Nord Department, the species was only reported once (in the Aa River) but the record was not confirmed (Toussaint & Bedouet, 2005).

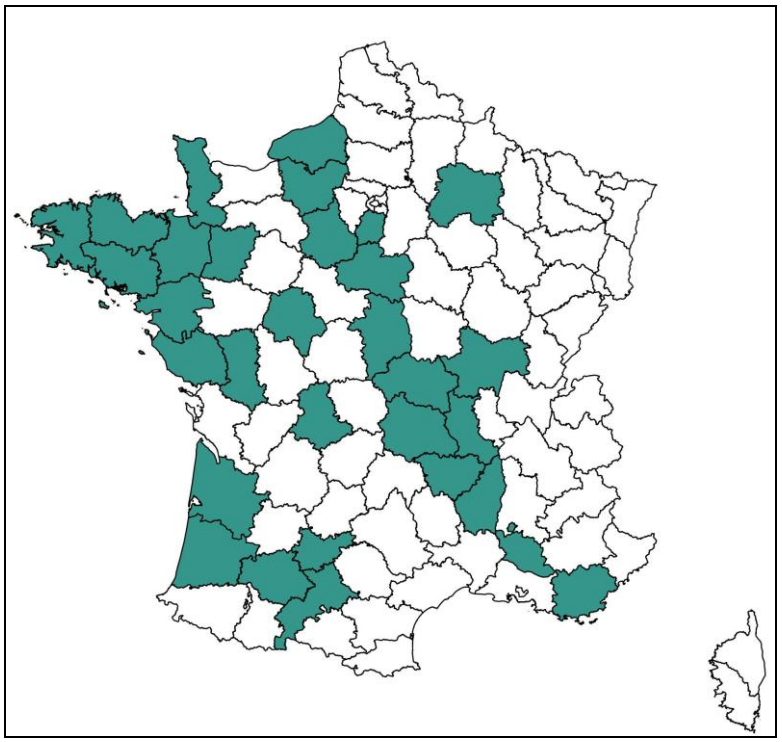

Figure 7: Distribution of *Egeria densa* in France (Source: réseau des Conservatoires Botaniques Nationaux, Décembre 2009).

- **Germany**

Cook & Urmi-König (1984) explain "it [*Egeria densa*] was first recorded outside cultivation in 1910 in the then incompleted Elster-Saale Canal near Leipzig, it was removed and has never since been recorded at this locality. It was then seen in 1914 in the River Niers but it did not persist. From 1932 until the 1950's it grew in a thermally polluted canal at Karlsruhe. From 1974 to 1976 it was recorded in a pit at Birkenfeld, Pfalz." The species is now present in six Länder and established in two, namely Nordrhein-Westphalia and Baden-Würtenberg (Hussner, 2010; Figure 8).

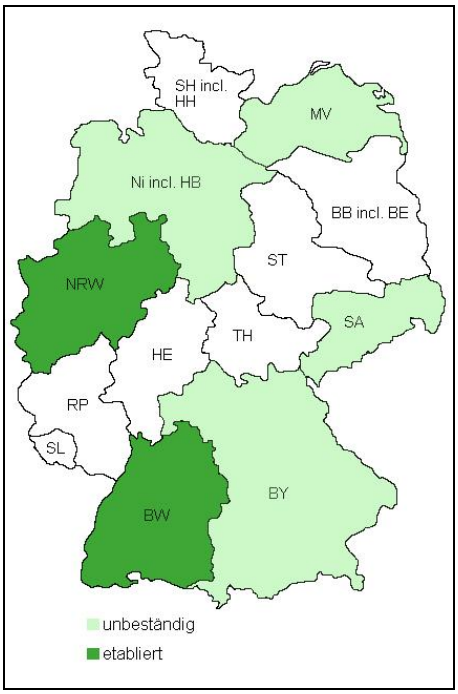

Figure 8: Distribution of *Egeria densa* in Germany, Green = Länder where the species is established, light green Länder where the species has been recorded. (Source: Hussner, 2010).

- **United Kingdom**

Egeria densa was first recorded in the Ashton Canal, Droylesden in 1953 (Cook & Urmi-König, 1984). It has increased from the first record in 1953 to five 10 km^2 by 1986, nine by 1995, 12 by 2000 and 17 by 2010 (Figure 9). In addition, the species was recently found in Ireland (Figure 10; National Biodiversity Data Centre, 2012). There was a rapid increase in the number of squares between 1986 and 2000, however this may be due to increased recording effort.

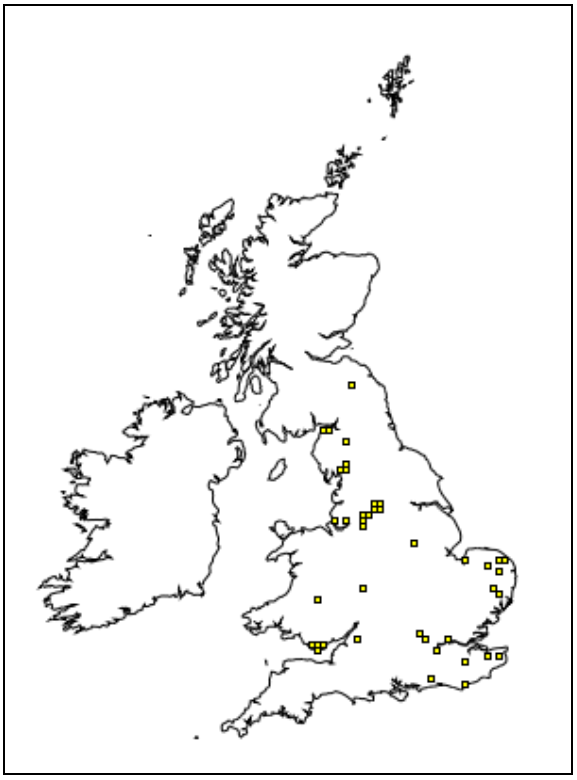

Figure 9: Distribution of *Egeria densa* in the UK according to records accessible through the NBN Gateway (http://data.nbn.org.uk/gridMap/gridMap.jsp?allDs=1&srchSpKey=NHMSYS0000458284 ; Accessed 15-12-2012).

Figure 10: Geographic distribution of *E. densa* in Ireland. The green dot on the upper left corner means that all known records are displayed. The color intensity of the record square from yellow to red reflects the increase in the number of records for each 10 km² (from National Biodiversity Data Centre, 2012).

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).

Egeria densa is widely sold for aquarium cultivation and as an "oxygenating plant" for ponds. Worldwide the principal means of entry is considered to be disposal of aquaria contents into local waterways, and spread is by vegetative means as many introduced populations comprise only male plants. Further introduction and spread are likely to continue.

E. densa is one of several invasive aquatic plants sold in Belgium by aquarium or water garden retailers, advertised on commercial websites, or occurring as contaminants among plants that are offered for sale (Kay & Hoyle, 2001; Haldford et al., 2011; Figure 11). *E. densa* is sold in most pet shops and even on markets, usually under the name "anacharis".

A recent study suggested that Belgian horticulture professionals had, until recently, a poor understanding of ecological issues caused by invasive plants, resulting from a lack of information and awareness (Vanderhoeven et al., 2011). Fortunately, progress has been made and it becomes well known that *E. densa*, and other plants as well, may become invasive in Belgium. The species is now black listed (Branquart, 2012) and several professional and non-professional horticulturists and gardeners have agreed with a code of conduct on invasive plants in Belgium (Halford et al., 2011), developed by the AlterIAS LIFE project (Alternatives for invasive plants, http://www.alterias.be/). As a result, the species progressively disappears from catalogues of aquatic nurseries.

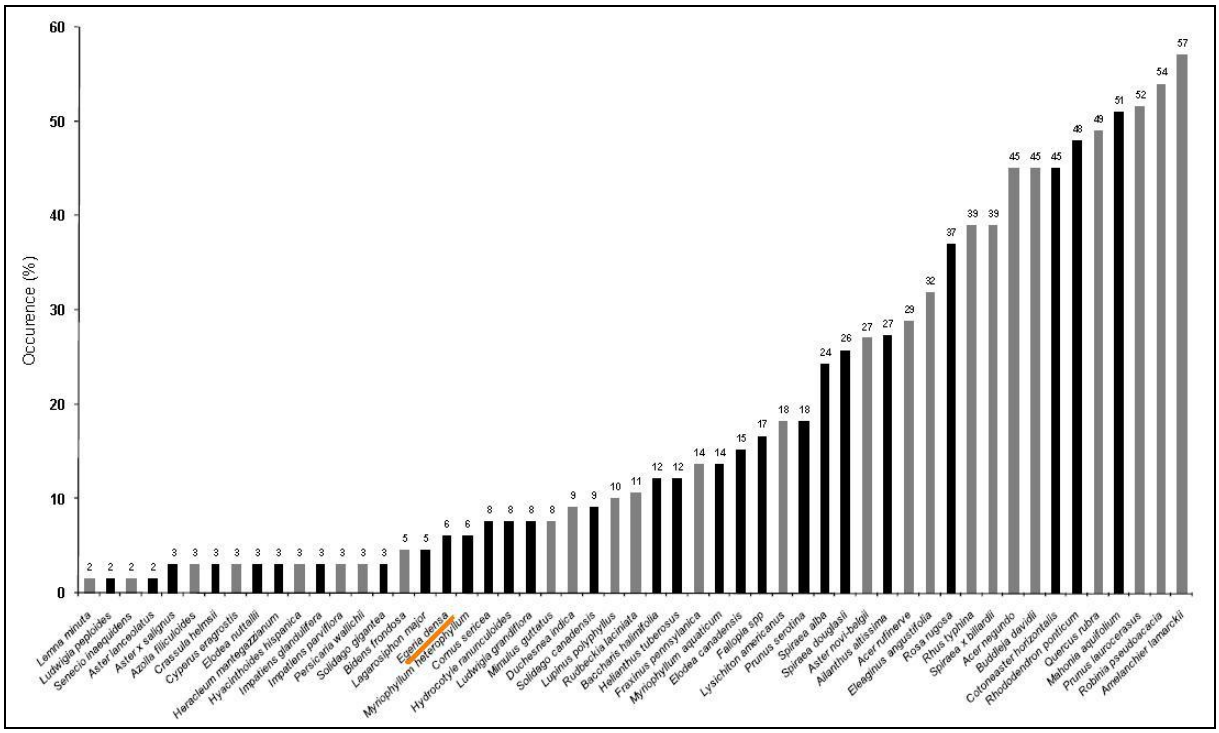

Figure 11: Occurrence of invasive plants (terrestrial and aquatic) sold in nurseries in Belgium (n = 67). Black bars: black listed species. Grey bars: watch listed species. *Egeria densa* (underlined in red) is present in 6% of the Belgian nurseries studied (modified from Halford et al., 2011).

There is a potential for natural colonization from neighboring areas where the species is established but this is very uncertain and undocumented in Europe. In the UK it is considered likely that most occurrences in the wild derive from plants thrown away when clearing ponds.

ENTRY IN BELGIUM

***Egeria densa* is a popular aquarium plant. Worldwide and in Belgium the principal means of entry is considered to be disposal of aquaria contents into local waterways. Spread is by vegetative means as many introduced populations comprise only male plants; seed formation has not been observed. Further introduction and spread are likely to continue. Nevertheless there is no evidence as yet that it is spreading by dispersal from naturalized population**.

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 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

Seeds and/or female flowers have never been reported from *Egeria densa* populations in the United States (Technical Information about Brazilian elodea (*Egeria densa)*, http://www.ecy.wa.gov/programs/wq/plants/weeds/aqua002.html) in New-Zealand (http://www.cabi.org/isc/Datasheet) or in Europe. The absence of sexual reproduction in introduced populations of *E. densa* emphasizes the importance of the vegetative growth phase of the plant. Specialized nodal regions described as double nodes occur every 6 to 12 nodes along a shoot. A double node consists of 2 single nodes separated by a greatly shortened internode. Double nodes produce lateral buds, branches, and adventitious roots. Only shoot fragments with double node regions can develop into new plants. The plant fragments readily and each fragment containing a double node has the potential to develop into a new plant. Plant root crowns also develop from double nodes along an old shoot. When a shoot sinks to the bottom during fall and winter senescence, a new root crown may develop at one or several double nodes along the new shoot. *Egeria densa* lacks specialized storage organs such as rhizomes or tubers and stores carbohydrates in stem tissues.

B/ Climatic requirements[2]

Temperature may be the most critical factor influencing *E. densa* metabolism (Barko & Smart, 1981; Yarrow et al., 2009). The optimum growth temperature is reported to be 15-17°C (and the maximum temperature for growth 25°C). Nevertheless, Riis et al. (2012) have experimentally demonstrated that *E. densa* growth rate and photosynthesis are higher in warm water (25-30°C) compared to colder one. Besides, in their study light availability had an overall stronger effect on growth rate and plant morphology than temperature (Figure 12). Indeed, they found that growth rate increased three-fold from low to high light (25% and 50 % of incident light available, respectively).

[2] 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.

E. densa appears to have some tolerance for cold water: it can survive winter in a ditch under a layer of ice (Haramoto & Ikusima, 1988). But if some sources mention that it can live for a while in ice, freezing is lethal according to others (Leslie, 1992); minimum temperatures and the maximum time it can withstand low temperatures are unknown.

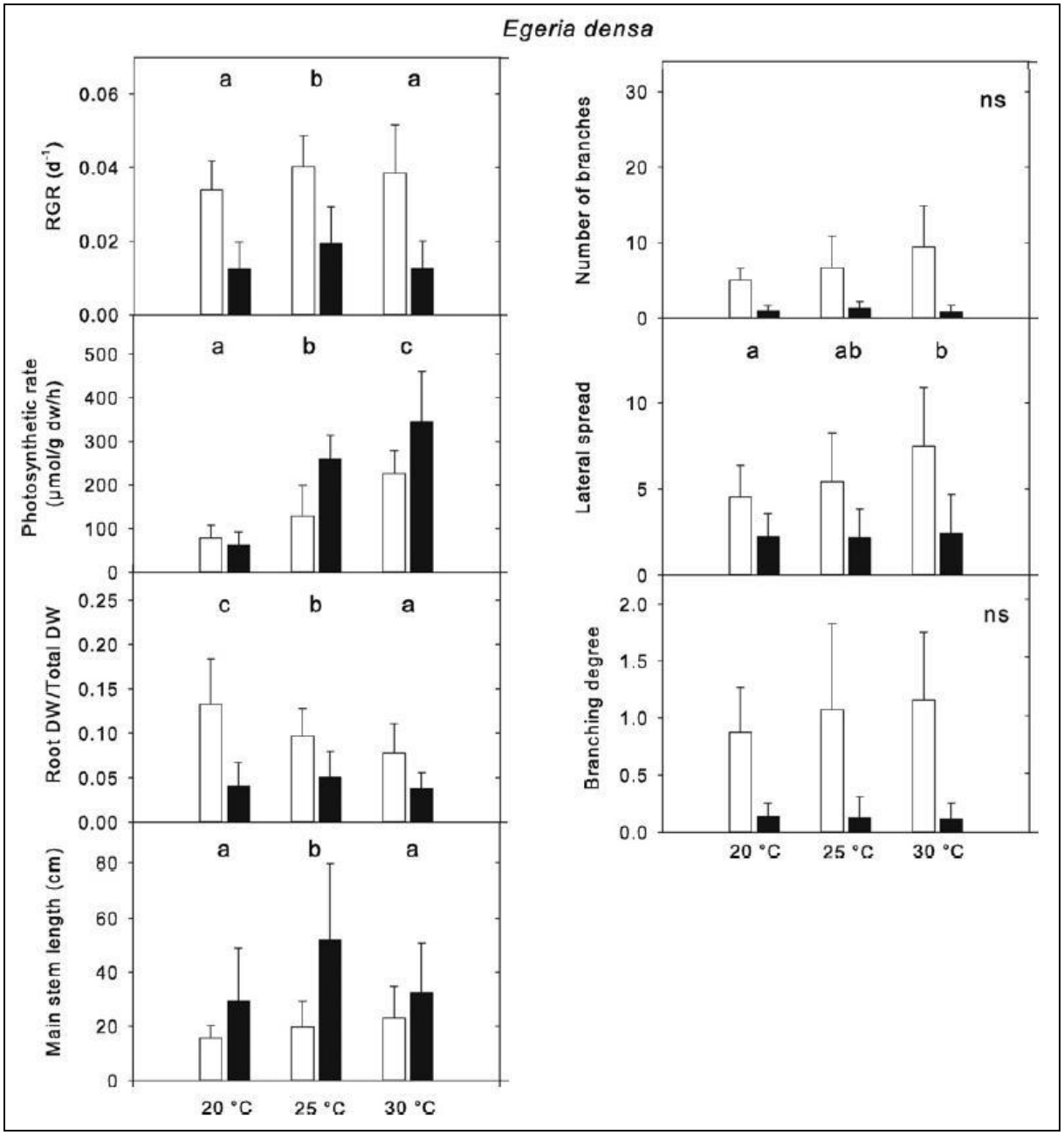

Figure 12: Results of an experiment testing the effect of temperature (20°C, 25°C and 30°C) and light (white bars: 50% incident light; black bars: 25% incident light ; Mean ± SD; n = 30) on morphological and physiological traits of *Egeria densa* after six weeks in outdoor growth tanks. Letters indicate significant differences between the three temperatures given by a two-way ANOVA analysis; ns indicates no significance; RGR and DW mean Relative Growth Rate and Dry Weight, respectively. It clearly appears that *Egeria densa* performs best (*i*) under warm water conditions and (*ii*) under higher light availability (50% incident light). Modified from Riis et al. (2012).

C/ Habitat preferences[3]

In its native range it is usually found in still water between 1 and 2 m deep, it is less common in shallow water and infrequent in flowing water. Outside its native range, it is found in both still and flowing water (up to 4 m deep). It appears to be confined to warm-temperate and cool subtropical conditions; in tropical or subtropical regions, it either occurs at high altitudes (to 2175 m) or in cold springs. *Egeria densa* tolerates a large range of pH. Although it seems to be somewhat more common in acid and humus-rich conditions, it also grows in calcareous eutrophic water. Ample light is required for photosynthetic activity and thus it cannot tolerate shade. Strong vertical growth and ability of unattached shoots to float loosely below the surface nevertheless enables it to develop in deep and turbid water.

D/ Food habits[4]

NA

E/ Control agents

No natural control agents have been detected within introduced range of the species. Grass carp (*Ctenopharyngodon idella)* triploids have been tested and successfully used as a management tool in New-Zealand. Triploid grass carp find *E. densa* highly palatable and the plant is highly preferred over most species native to this area. In practice, however, grass carp have often been found to remove the entire submersed aquatic community and hence introduction should be undertaken with great care.

F/ Establishment capacity in Belgium

There are no good examples of invasive behaviour of *Egeria densa* in climatic and environmental conditions similar to those in Belgium. *Egeria densa* is probably not well adapted to the eco-climatic conditions prevailing in Belgium (it can probably not survive our prolonged winter freezing temperatures). The slow rate of spread observed in the UK would suggest that dispersal is not particularly effective, although it is clearly increasing. It is likely that most populations in the UK (and Belgium) result from separate successive disposal events of aquarium or pond plants into the wild, although the increasing number of clustered populations may be due to spread of fragments. Global warming can change this and enhance the future establishment of *Egeria densa* in at least in the lower part of the country.

G/ Endangered areas in Belgium

Considering what it is observed in neighboring countries and taking into account expected climatic change, a medium risk status is appropriate for most of the Belgian districts. The sensitivity of *Egeria densa* to freezing does not permit the Ardenne district to be colonized, even in the future.

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

[4] For animal species only.

Figure 13: Threat from *Egeria densa* on Belgian endangered areas. Based on the species climatic requirement.

Establishment capacity in the Belgian geographic districts:

Districts in Belgium	**Environmental conditions for species establishment**[5]
Maritime	Sub-optimal
Flandrian	Sub-optimal
Brabant	Sub-optimal
Kempen	Sub-Optimal
Meuse	Sub-Optimal
Ardenne	Inadequate
Lorraine	Sub-optimal

ESTABLISHMENT CAPACITY AND ENDANGERED AREAS IN BELGIUM

Introduced populations of *Egeria densa* in Belgium (and north-western Europe) are still isolated, but records are increasing, probably due to multiple introduction events and limited spread in rivers.

***Egeria densa* has a very wide ecological amplitude. It thrives in various types of freshwater habitats, from acidic to eutrophic. It prefers slow flowing waters but may also be found in still waters. This aquatic weed is light demanding but is able to develop in deep and turbid waters. Habitat characteristics of most Belgian freshwater habitats are within the ecological**

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

requirements of *Egeria densa*. Belgium is therefore a country where the species shows potential establishment capacity.

At present the species does not show effective natural spreading, this is probably due to its sensitivity to freezing in winter. With the expected rise in temperature due to climate change and being essentially a freshwater opportunist, most wetlands, streams and ponds (including sensitive areas, nature reserves and Natura2000 sites), except the Ardenne (and possibly Lorraine) district(s) , are considered vulnerable to *E. densa* invasion.

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

Egeria densa spreads naturally by vegetative means only as non native populations comprise only male plants. Fragments may be transported over longer distances by runnning water. The expansion rate in northern Europe seems rather limited.

B/ Human assistance

It is highly likely that most populations in western Europe (Belgium included) are the result of separate successive disposal events of aquarium or pond plants into the wild. *E. densa* has been continually distributed, mainly by trade, for use in aquaria. When aquaria are cleaned, plants can enter water systems and so spread to lakes and other water bodies. Noting its continued and widespread use and availability, it is highly likely that further introductions will occur and that it will become naturalized in local water systems. However, as its invasive character becomes recognized, it is increasingly regulated, notably in the USA and New Zealand, also recently in South Africa.

DISPERSAL CAPACITY

Human activities can greatly enhance dispersal capacity if precautions are lacking. The species capacity to colonize remote areas is clearly linked to human assisted dispersion, mainly through trade and disposal of aquaria contents into local waterway. In the non-native area, short distance dispersal by vegetative means is facilitated by accidental transport on human clothes and footwear, machinery, boats or fishing equipment. Widespread establishment is more likely to occur in waterways and standing waters within the floodplain of infected streams.

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

A/ Competition

In areas of significant infestation (such as the USA or Australia) *Egeria densa* is reputed to out-compete native aquatic plants, blocking light needed by other plants.

It would be interesting to consider the differences between the role of *E. densa* in natural systems in its native range versus its role in human-created aquatic systems and/or systems where it behaves invasively. However, there is surprisingly little information on the ecology of any of the species of the genus *Egeria* in their native region (Tavechio & Thomaz, 2003). In fact, many of the studies in the native range of *Egeria* examined man-made reservoirs that were invaded and dominated by *E. densa* or *E. najas* (e.g. Oliveira et al. 2005).

B/ Predation/herbivory

NA

C/ Genetic effects and hybridization

None known and not to be expected as there are no European congeneric species.

D/ Pathogen pollution

Not to be expected.

E/ Effects on ecosystem functions [LIKELY]

Egeria densa has been described as an ecosystems engineer (Figure 14). In areas of significant infestation (such as the USA or Australia) *Egeria densa* is reputed to disrupt natural erosion-deposition processes, disrupt the movement of animals, block light needed for photosynthesis, disrupt predator-prey relationships, prevent wind mixing, lead to local oxygen depletion, enhance mosquito breeding and increase water temperature by absorbing sunlight, while massive die-back can increase nutrient loads to the water and sediments. None of these impacts are likely in Belgium, unless populations would grow significantly.

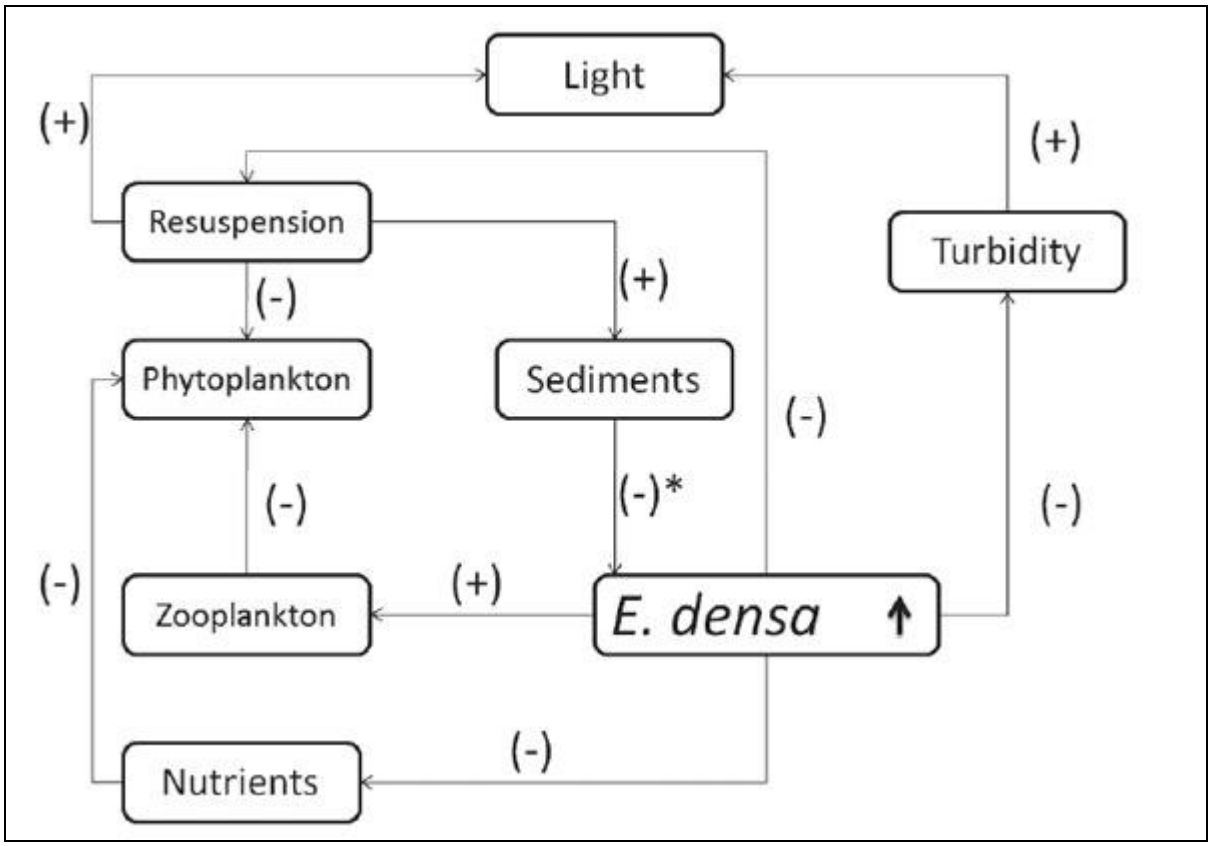

Figure 14: *Egeria densa* as ecosystem engineer (sensu Jones et al., 1994). The presence of high coverage of *E. densa* decreases water turbulence, decreasing sediment re-suspension and increasing sedimentation. The decrease in re-suspension increases the light available in the water column maintaining the clear water ecosystem state. It also decreases the standing stock of phytoplankton by sequestering nutrients into the sediments. It finally increases the concentration of zooplankton since it acts as a refuge decreasing its predation. However, in the long term these feedback mechanisms may self-generate adverse conditions for development through the increase in sediment accumulation (-)*.

ENVIRONMENTAL IMPACTS.

In areas of significant infestation (such as the USA or Australia) *Egeria densa* is reputed to disrupt natural erosion-deposition processes, disrupt the movement of animals, out-compete native aquatic plants, block light needed for their photosynthesis, disrupt predator-prey relationships, prevent wind mixing, lead to local oxygen depletion, create mosquito breeding areas and increase water temperature by absorbing sunlight, while die back can increase nutrient loads to the water. None of these impacts have been observed at a large scale in Belgium yet but are likely if populations increase significantly.

2.2.2 Other impacts

A/ Economic impacts

Although there are positive economic impacts resulting from the trade in *E. densa*, they are strongly countered by the costs of control in many areas where it has become a serious problem. Removal of *E. densa* from lakes and reservoirs in the USA costs some states several million dollars per annum (CABI.org web site). California has allocated two million dollars in 2000 to manage the problems with Brazilian elodea in the Sacramento-Delta area (http://www.ecy.wa.gov/programs/wq/plants/weeds/egeria.html).

B/ Social impacts

In areas of significant infestation (e.g. America, Australia) dense mats of *E. densa* deleteriously affect recreational activities such as fishing, swimming or boating (CABI.org web site). It can create a safety hazard for boaters, obstruct channels, marinas and irrigation systems, disrupt navigation and make water-sports, fishing, and swimming impractical.

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.

If international trade continues, further introductions and colonization are likely. In north-western Europe this pathway is the main cause of new site occurrences. In Belgium and neighboring countries, the natural spread of *Egeria densa* seems to be restricted by low survival in winter time with (prolonged) freezing-over as a limiting factor.

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.

Experiences with *E. densa* as an invasive species differ according to region. In Australia, New Zealand and parts of the United States, much work has been done to understand the invasive potential of *E. densa*, find eradication methods, and inform the public so as to avoid further introductions (Roberts et al. 1999).

(i) Prohibition of organism importation, trade and holding

Considered to be the best way to limit risk of propagation. New introductions are most likely due to the high frequency of sale in the horticultural trade**.** Strong restrictions on import, trade and commercial culture must be proposed to avoid the continuation of establishment of new feral populations in the wild.

Alternative species for trade do exist.

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

Legislation to prohibit release in the wild should be taken into serious consideration. Disposal of garden and pond waste must be managed responsibly. Vehicles, boats, equipment and clothing used at infested sites should be meticulously cleaned to avoid dissemination of plant fragment.

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 general, little attention is given to submerged plants, even by conservationists, and specific survey methods may be necessary (raking, diving, repeated observations,…) to detect less abundant species. Early detection in streams, turbid and deeper waters may be quite difficult. Although very closely related to *Elodea* spp., these species are usually readily distinguished in the field by experienced observers, even in the vegetative state. *Egeria* are often much more robust with thicker and still longer stems and leaves are longer. It might go unrecorded due to confusion with the latter.

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

The side effect of chemicals, physical 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.

- Chemical

Excellent control of *E. densa* with diquat and complexed copper, endothall dipotassium salt, and endothall and complexed copper were reported. Good control was obtained with fluridone. California reports good control achieved using complexed copper alone.

- Physical

Mechanical removal such as cutting, hand pulling or netting is feasible for small infestations. Local control (in swimming areas and around docks) can be achieved by covering the sediment with an opaque fabric that blocks light from the plants. Managers of reservoirs and some lake systems may have the ability to lower the water level or drain the entire basin to manage aquatic plants. This will only eliminate *Egeria* effectively if the exposed substrate is allowed to dry completely. Because this plant spreads readily through fragmentation, mechanical controls such as cutting, harvesting, and rotovation (underwater rototilling) should be used only when the extent of the infestation is such that all available niches have been filled. Eutrophication control can help to avoid nuisance development.

- Biological

As *E. densa* is highly palatable, the stocking with certain fish such as grass carp (*Ctenopharyngodon idella*) has been suggested and tested. Triploid grass carp find *E. densa* highly palatable (when older than fingerlings) and have been successfully employed as a management tool. *E. densa* is highly preferred over most other species and theoretically, it should be possible to remove *E. densa* while favoring the growth of native species. In practice, however, grass carp often remove all submersed

aquatic vegetation and hence introduction of grass carp should be undertaken with great care (The Washington State Department of Ecology, 2003).

Fusarium sp. (isolation FCAV#940) has potential for the biological control of the macrophytes *Egeria najas* and *E. densa* (Mendes et al., 2004). Barreto et al. (2000) report that, R.A. Pitelli at UNESP (Universidade Estadual Paulista) worked for several years on the bio-control of *E. densa* on a project funded by CESP (Center for Environmental Science and Policy). Laboratory tests showed that eight *Fusarium sp.* isolates appeared to have potential for the development as bio-control agents. One isolate of *Fusarium graminearum* was the most pathogenic and the easiest to be manipulated. Plants of both species of *Egeria* developed progressive chlorosis followed by necrosis and complete tissue disintegration after being exposed to inoculum of this isolate. No information is available on effectivity in the field or possible suitability (incl. effecs on native species) within the territory.

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

Use of mechanical control methods can enhance its rate of spread. The ability to propagate from small stem fragments means that repeated removal will be required, or even that infestations may spread if mechanical removal is not adequate.

As already mentioned grass carp have been noticed to often remove the entire submersed community and hence introduction of grass carp (an exotic species) should be undertaken with great care.

Use of chemicals herbicide such as diquat in water bodies leads to evident environmental risks.

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

Probably yes. There are efficient herbicides available for the control of this species but their use is restricted by legal constraints and environmental concerns so it should not be encouraged. Mechanical removal such as cutting, hand pulling or netting is considered feasible for small infestations but can encourage dispersal, spread and establishment to new areas if carelessly practiced. Prolonged lowering of the water level can eliminate *Egeria densa* in ponds and some reservoir systems.

Biological control is not yet possible, but mechanical control and harvesting, combined with Grass Carp - if not prohibited or threatening native vegetation and only if complete removal of these fish afterwards can be guaranteed - may be an option for isolated (small) sites at a very early stage of invasion.

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

Possibly not, but localized control (in swimming ponds and around docks) can be achieved by covering the sediment with an opaque fabric which blocks light from the plants.

RISK MANAGEMENT

The main current pathway of introductions of *Egeria densa* in Belgium remains its sale as an ornamental plant for aquariums and ponds, and its subsequent release in the wild. This pathway is however decreasing thanks to education actions carried out in the country (e.g. in the framework of the AlterIAS LIFE project). Once established, vegetative dispersion occurs.

A unified, strengthened legislation should be established <u>in Europe</u> to ensure a total ban on import, trade and holding of *Egeria densa* and other (potentially) invasive aquatic plants. Fortunately, for *E. densa*, populations are still at an early invasion stage in Belgium and

populations are restricted to small isolated areas. As a result, prohibition of importation, trade and holding in Belgium could effectively prevent its entry, establishment and spread.

***Egeria densa* is difficult to detect at early stages of invasion, and therefore control or eradication actions often start when the plant is already well-established.**

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 (mechanical removal).

LIST OF REFERENCES

Alfasane, A., Khondker, M., Islam, S. & Bhuiyan, A. H. (2010). *Egeria densa* Planchón (Hydrocharitaceae): a new angiospermic record for Bangladesh. Bangladesh J. Plant Taxon. 17 (2): 209-213.

Barko, J. W. & Smart, R. M. (1981). Comparative influences of light and temperature on the growth and metabolism of selected submersed freshwater macrophytes. Ecological Monographs 51: 219-235.

Barreto, R., Charudattan, R., Pomella, A. & Hanada, R. (2000). Biological control of Neotropical aquatic weeds with fungi. Crop Protection 19: 697-703.

Branquart, E., Stiers, I., Triest, L., Vanderhoeven, S., Van Landuyt, W., Van Rossum, F. & Verloove, F. (2010) Harmonia database: *Egeria densa*. Harmonia version 1.2, Belgian Forum on Invasive Species, accessed on 21-02-2013 from: http://ias.biodiversity.be/.

Branquart, E. (Ed.). (2012). Alert, black and watch lists of invasive species in Belgium. Harmonia version 1.2, Belgian Forum on Invasive species, accessed on 12-02-2013 from: http://ias.biodiversity.be/.

Cook, C. D. K. & Urmi-König, K. (1984). A revision of the genus *Egeria densa* (Hydrocharitaceae). Aquatic Botany 19: 73-96.

DEMNA Database, January 2013

Denys, L., Packet, J. & Van Landuyt, W. (2004). Neofyten in het Vlaamse water : signalement van vaste waarden en rijzende sterren. Natuur.focus 3(4): 120-128.

Duggan, I. C. (2011). Aquaria. In: Simberloff, D. & Rejmánek, M. Encyclopedia of Biological Invasions, pp. 32-35, Berkeley, Los Angeles: University of California Press.

Dutartre, A., Haury, J. & Jicorel, A. (1999). Succession of *Egeria densa* in a drinking water reservoir in Morbihan (France). Hydrobiologia 415: 243–247.

Feuillade, J. (1961a). Une plante aquatique nouvelle pour la France *Elodea densa* (Planch.) Casp. Bulletin de la Société Linnéenne de Normandie 10: 47–51.

Feuillade, J. (1961b). Note complémentaire sur *Elodea densa* (Planch.) Casp. Bulletin de la Société Linnéenne de Normandie 10: 185–188.

Halford, M., Heemers, L., Mathys, C., Vanderhoeven, S. & Mahy, G. (2011). Socio-economic survey on invasive ornamental plants in Belgium. Final report February 2011. LIFE + "Information & Communication" AlterIAS project. 25 pp. + annexes.

Haramoto, T. & Ikusima, I. (1988). Life cycle of *Egeria densa* Planch., an aquatic plant naturalized in Japan. Aquat. Bot. 30: 389-403.

Hussner, A. & Lösch, R. (2005). Alien aquatic plants in a thermally abnormal river and their assembly to neophyte dominated macrophyte stands (River Erft, Northrhine-Westphalia). Limnologica 35: 18-30.

Hussner, A. (2010). Die aquatischen Neophyten in Deutschland – Eine übersicht. *Egeria densa* Planchon., Dichte Wasserpest, Hydrocharitaceae.
http://www.aquatischeneophyten.de/Bilder/Verbreitungskarten%20deutsche%20Version/Deutschlandkarte%20Egeria%20densa.jpg

IFAS - Center for aquatic and invasive plants; Univerisity of Florida. (2013). http://plants.ifas.ufl.edu/ Accessed 12-02-2013.

ISC - Invasive Species Compendium. (2012). Datasheet - *Egeria densa* (leafy elodea); available at: http://www.cabi.org/isc/?compid=5&dsid=20491&loadmodule=datasheet&page=481&site=144; Accessed 12-02-2013.

ISSG (Invasive Species Specialist Group) (2006) *Online fact sheets* Global Invasive Species Database, IUCN.

Jones, C., Lawton, J., & Shachak, M. (1994). Organisms as ecosystem engineers. Oikos 69: 373-386.

Kay S. H. & Hoyle S. T. (2001). Mail order, the Internet, and invasive aquatic weeds. Journal of Aquatic Plant Management 39: 88-91.

Leslie, A. (1992). Copper herbicide use-patterns in Florida waters. Florida Department of Natural Resources. Tallahassee, Florida, USA. 9 pp.

Mendes, D., Pitelli, R. A & Coelho, L. (2004). Efeito de concentrações de herbicidas sobre aspectos biológicos de *Fusarium* sp. (isolado FCAV#940). Planta Daninha 22: 85-93.

Mony, C., Koschnick, T. J., Haller, W.T. & Muller, S. (2007). Competition between two invasive Hydrocharitaceae (*Hydrilla verticillata* (L.f.) (Royle) and *Egeria densa* (Planch)) as influenced by sediment fertility and season. Aquatic Botany 86: 236-242.

Muller, S. (2004). Plantes invasives en France : état des connaissances et propositions d'actions. Publication scientifique du Museum d'Histoire naturelle, Patrimoines naturels n°62.

National Biodiversity Data Centre. (2012). Distribution maps of invasive species and problematic plants in the National Invasive. Species Database as of 24/08/2012. http://invasives.biodiversityireland.ie/wp-content/uploads/Inv-distribution-maps-Aug124.pdf

Nienhuis, P. (2008). Exotics and invasions of plants and animals. In: Nienhuis, P. Environmental history of the Rhine—Meuse Delta. Springer Science + Business Media, B.V. Pp. 451-479.

Oliveira N. , Sampaio E., Pereira S. & Moura Junior A. (2005) Regeneration capacity of *Egeria densa* in Reservoirs in Paulo Afonso, Bahia. Planta Daninha23: 363-369.

Riis, T., Olesen, B., Clayton, J. S., Lambertini, C., Brix, H. & Sorrell, B. K. (2012). Growth and morphology in relation to temperature and light availability during the establishment of three invasive aquatic plant species. Aquatic Botany 102 : 56– 64.

Roberts, D., Church, A. & Cummins, S. (1999). Invasion of *Egeria* into the Hawkesbury-Nepean River, Australia. Journal of Aquatic Plant Management 37: 31-34.

Robijns, J., Vanhecke, L. & Asperges, M. (2002). *Egeria densa*, een valse waterpest met grote bloemen, nieuw voor de Belgische flora. *Dumortiera* 79: 17-19.

Rose, F. (2006). The wild flower key - How to identify wild flowers, trees and shrubs in Britain and Ireland. Warne, Penguin Group, England. 576 pp.

St. John, H. (1961). Monograph of the genus "*Egeria*" Planchom. Darwiniana 12: 293-307.

Tavechio, W. & Thomaz, S. (2003). Effects of light on the growth and photosynthesis of *Egeria najas* Planchón. Brazilian Archives of Biology and Technology 46: 203-209.

Thiébaut, G. (2007). Non-indigenous aquatic and semiaquatic plant species in France. In: F. Gherardi (Ed.), Biological invaders in inland waters: profiles, distribution and threats. Series: Invading Nature – Springer Series in Invasion Ecology. Springer, Vol 2, p. 209-229.

Toussaint, B. & Bedouet, F. (2005). Les espèces végétales invasives des milieux aquatiques et humides du bassin Artois-Picardie. Agence de l'Eau Artois-Picardie, 38 pp.

Vanderhoeven, S., Piqueray, J., Halford, M., Nulens, G., Vincke, J. & Mahy, G. (2011). Perception and understanding of invasive alien species issues by nature conservation and horticulture professionals in Belgium. Environmental Management 47: 425-442.

Washington State Department of Ecology. (2003). Technical information about *Egeria densa* (Brazilian Elodea). Water Quality Program: Non-Native Freshwater Plants.

Winterton, S. & Scher, J. (2007). Aquarium and pond plants of the world, Edition 2.0, Lucid v. 3.4. USDA/APHIS/PPQ Center for Plant Health Science and Technology, North Carolina State University, and California Department of Food and Agriculture. [12-02-2013] <http://www.lucidcentral.org/keys/aquariumplants2/>

Yarrow, M., Marín, V. H., Finlayson, M., Tironi, A., Delgado, L. D. & Fischer, F. (2009). The ecology of *Egeria densa* Planchon (Liliopsida: Alismatales): A wetland ecosystem engineer? Revista Chilena de Historia Natural 82: 299-313.

Internet sites consulted:

http://www.cabi.org/isc/Datasheet

http://ias.biodiversity.be

Manual of the Alien Plants of Belgium (http://alienplantsbelgium.be)

http://data.nbn.org.uk/gridMap/gridMap.jsp?allDs=1&srchSpKey=NHMSYS0000458284

http://www.q-bank.eu

http://www.aquatischeneophyten.de/Bilder/Verbreitungskarten%20deutsche%20Version/Deutschlandkarte%20Egeria%20densa.jpg

http://www.ecy.wa.gov/programs/wq/plants/weeds/aqua002.html