Risk analysis report of non-native organisms in Belgium

Risk analysis of the perennial water primrose

Ludwigia grandiflora (Michx.) Greuter & Burdet.

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Risk analysis of the perennial water primrose *Ludwigia grandiflora* (Michx.) Greuter & Burdet.

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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:

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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 <u>initiation process</u> which involves identifying the organism and its introduction pathways that should be considered for risk analysis in relation to Belgium, (2) the <u>risk assessment stage</u> 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 <u>risk management stage</u> 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.*

Executive summary

PROBABILITY OF ESTABLISHMENT AND SPREAD (EXPOSURE)

Entry in Belgium	Although L. grandiflora is regulated in some neighbouring countries, the probability of entry in Belgium by intentional import as an ornamental aquatic plant for outdoors is very likely.
Establishment capacity	Despite the very limited information available on thermal requirements, Ludwigia grandiflora is likely to further establish self-sustaining populations in most of Belgium. The species is indeed well established in neighbouring areas presenting similar climatic conditions. Appropriate habitats are present in the Belgian territory and include high value habitats; Natural enemies present in Europe are at present unlikely to affect the invasiveness of the species.
Dispersion capacity	Ludwigia grandiflora can easily disperse both naturally and with human assistance from cultivation ponds. It shows a high dispersal rate through vegetative fragments within a catchment, providing that suitable habitats are present. Human activities are principally responsible for long distance transport, with zoochory potentially contributing as well.

EFFECT OF ESTABLISHMENT

Environmental impacts	L. grandiflora develops quickly and produces/forms very thick monospecific floating carpets/mats at the surface of water bodies. This alters the physical-chemical water quality (reduction of light and dissolved oxygen). Allelopathy reduces the germination and survival rates of other plant species and contributes to the significant changes of ecosystem processes. The species outcompetes most native water plants and creates an anoxic environment detrimental to many plant and animal species. L. grandiflora is therefore considered as a transformer species according to Richardson et al. (2000). Further establishment of Ludwigia grandiflora in Belgium will consequently result in important environmental changes through alteration of both plant and animal communities in invaded habitats, as well as extensive transformation of invaded ecosystem processes and functions. Hybridization with native congeneric species seems unlikely.

RISK MANAGEMENT

The prohibition of Ludwigia grandiflora import, trade and exchange is considered as an efficient measure for reducing further establishment of the species into the wild, coupled with communication and voluntary actions such as codes of conducts in order to reduce propagule pressure.

As the species is already present in a large part of Belgium, prevention, early detection and populations control should be used complementarily to limit further invasion, in particular in high biological value habitats. This is particularly important considering that large scale eradication programs seem very unlikely to succeed..

Résumé

PROBABILITE DE NATURALISATION ET DE DISSEMINATION DANS L'ENVIRONNEMENT

Introduction en Belgique	Bien que la mise sur le marché de la jussie à grandes fleurs soit réglementée dans la plupart des pays limitrophes, sa voie d'introduction la plus probable est l'importation intentionnelle dans les plans d'eau extérieurs. Le risque de transfert vers des habitats naturels ou semi-naturel est élevé.
Capacité de naturalisation	Il existe peu d'informations relatives aux exigences thermiques de la jussie à grandes fleurs. Néanmoins, cette dernière semble capable de former des populations viables sur la plupart du territoire belge. L'espèce s'est en effet bien établie sur des territoires voisins présentant des conditions climatiques semblables. Des habitats appropriés sont disponibles sur le territoire belge et comprennent des sites de haut intérêt biologique. Les ennemis naturels présents en Europe semblent inaptes à contrer l'invasion de l'espèce.
Capacité de dissémination	La jussie à grandes fleurs peut facilement se disperser à partir des mares où elle a été introduite, soit naturellement soit via une assistance humaine (élimination de déchets verts). Un fragment de plante suffit pour établir une nouvelle population. Les activités humaines sont le principal vecteur de dissémination, surtout pour les longues distances. La zoochorie pourrait également contribuer à la dispersion de la plante.

EFFETS DE LA NATURALISATION

Impacts environnementaux	La jussie à grandes fleurs peut former des populations monospécifiques denses de taille importante. Le tapis végétal flottant à la surface de l'eau altère la qualité physico-chimique de l'eau en réduisant l'entrée de lumière et d'oxygène dans l'eau. L'allopathie réduit le taux de survie et de germination d'autres plantes et modifie le fonctionnement des écosystèmes aquatiques. La jussie à grandes fleurs prend le pas sur les autres plantes aquatiques et crée des conditions anoxiques défavorables à la faune et à la flore. Elle est considérée comme une espèce « transformatrice » selon Richardson et al. (2000). L'expansion de l'espèce sur le territoire belge est susceptible de causer d'importants dommages environnementaux au travers de l'altération des communautés végétales et animales et du dysfonctionnement des milieux aquatiques colonisés. Il ne semble pas y avoir d'hybridation avec des espèces indigènes.

GESTION DU RISQUE

Une mesure jugée efficace pour réduire les risques d'établissement de la jussie à grandes fleurs dans la nature est l'interdiction du commerce, de l'importation et des échanges horticoles de cette espèce, couplée à des actions de communication et des codes de conduite, afin de diminuer la pression de propagules.

Etant donné que l'espèce est déjà présente en Belgique, des mesures de prévention, de détection précoce et de gestion de nouvelles populations devraient compléter cette interdiction afin de limiter la colonisation et d'éviter l'apparition de nouveaux foyers d'invasion, spécialement dans les zones de grand intérêt biologique.

Ceci est d'autant plus important que la réussite d'actions d'éradication à large échelle semble peu probable.

Samenvatting

WAARSCHIJNLIJKHEID VAN VESTIGING EN VERSPREIDING (BLOOTSTELLING)

Introductie in België	Hoewel L. grandiflora in sommige buurlanden gereglementeerd is, is de kans vrij groot dat de soort in België terechtkomt door opzettelijke invoer voor sierdoeleinden.
Vestigingsvermogen	Ondanks de eerder summiere informatie over de thermische vereisten van de soort is het erg waarschijnlijk dat populaties van de waterteunisbloem zich over zowat het volledige Belgische grondgebied kunnen handhaven. De soort is in omliggende landen met gelijkaardige klimaatomstandigheden inderdaad goed gevestigd en is ook al lange tijd gevestigd in Vlaanderen. Op Belgische grondgebied komt geschikt habitat voor, waaronder gebieden met een hoge biologische waarde. De in Europa aanwezige natuurlijke vijanden lijken geen hindernis te vormen voor de verdere invasie van de soort.
Verspreidingsvermogen	Ludwigia grandiflora kan zich gemakkelijk op een natuurlijke manier alsook met de hulp van de mens verspreiden vanuit kweekvijvers en reeds gevestigde populaties. Vegetatieve fragmenten hebben een sterke verspreidingscapaciteit op voorwaarde dat er geschikte habitats aanwezig zijn. Menselijke activiteiten zijn de grootste oorzaak voor transport over grotere afstanden, hoewel ook een bijdrage van zoöchorie (verspreiding door dieren) niet mag worden onderschat.

EFFECTEN VAN VESTIGING

Milieu-impact	Ludwigia grandiflora ontwikkelt zich snel en vormt dikke, monospecifieke drijvende matten aan het wateroppervlak. Dit tast de fysisch-chemische karakteristieken van het water en de waterkwaliteit aan (vermindering van licht en opgeloste zuurstof). Allelopathie vermindert de kiemcapaciteit en het overlevingspercentage van andere plantensoorten en draagt bij tot aanzienlijke veranderingen van de ecosysteemprocessen. De soort verdringt de meeste inheemse waterplanten en creëert een anoxische omgeving die schadelijk is voor tal van plant- en diersoorten. Om die reden wordt L. grandiflora door Richardson et al. (2000) beschouwd als een "transformer" soort. Verdere verspreiding en vestiging van waterteunisbloem in België zal dus aanzienlijke milieuveranderingen in aquatische ecosystemen veroorzaken door aantasting van zowel de planten- als dierengemeenschappen en een verregaande transformatie van de ecosysteemprocessen en -functies van systemen waarin de invasie plaatsvindt. Hybridisatie met nauw verwante inheemse soorten is weinig waarschijnlijk.

RISICOBEHEER

Het verbod op invoer, verkoop en handel in Ludwigia grandiflora wordt beschouwd als een doeltreffende maatregel voor het beperken van de verdere vestiging van de soort in het wild. Complementair hiermee kunnen communicatie naar vijvereigenaars en vrijwillige acties zoals gedragscodes het aantal introducties verminderen.

Omdat de soort al in grote delen van België aanwezig is, dient een mechanisme voor preventie, vroegtijdige opsporing en populatiecontrole geïmplementeerd te worden om de verdere invasie, vooral in habitats met een hoge biologische waarde, te beperken. Dit is bijzonder belangrijk omdat grootschalige uitroeiingsprogramma's weinig kans op slagen in het vooruitzicht stellen.

STAGE 1: INITIATION

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

1.1 ORGANISM IDENTITY

Scientific name:	*Ludwigia grandiflora* (Michx.) Greuter & Burdet.
Synonyms:	*Jussiae grandiflora* Michx., *Jussiaea michauxiana* Fernald, nom. illeg., *Jussiaea repens* L. var. *grandiflora* Micheli, *Jussiaea uruguayensis* Cambess, *Ludwigia uruguayensis* (Cambess.) H.Hara, *Ludwigia hexapetala* (Hook. & Arn.) Zardini, H.Y.Gu & P.H. Raven and *Ludwigia uruguayensis* var. *major* (Hassler) Munz. *L. grandiflora* is likely to be traded under *Jussiaea*. The species may be imported as *L. peruviana or L. peruensis*.
Common name:	Perennial water primrose, Uruguyan primrose willow [En], Ludwigie à grandes fleurs, Jussie à grandes fleurs [Fr], Waterteunisbloem [Nl], Grosses Heusenkraut [De].
Taxonomic position:	Kingdom: Plantae / Phylum: Spermatophyta /Subphylum: Angiospermae /Class: Dicotyledonae /Order: Myrtales/ Family: Onagraceae/ Genus: *Ludwigia*

The identification of *Ludwigia* species in the section *Oligospermum* s.l. is difficult and results in numerous taxonomic adjustments and synonyms (Dandelot et al., 2005a). This is mainly because *Ludwigia* species form a polyploid complex. Zardini *et al*. (1991) observed two entities among plants treated as *Ludwigia uruguayensis* (Cambess.) H.Hara: a decaploid entity (2n = 80) and a hexaploid one (2n = 48). They differ by quantitative, intergrading morphological characteristics and are known to produce hybrids of intermediate morphology in sympatric zones of the United States (Nesom & Kartesz, 2000). A biosystematic and cytogenetic analysis of individuals collected in France has shown that all *L. grandiflora* individuals belong to the decaploid entity (Dandelot et al. 2005a). *L. grandiflora* and *L. peploides* are thus particularly difficult to differentiate morphologically, especially when flowers are absent. Consequently, publications often refer to '*Ludwigia* spp.' in general without further differentiation.

1.2 SHORT DESCRIPTION

Ludwigia grandiflora is a herbaceous perennial aquatic plant forming dense mats. It usually shows two growth forms: (1) the plant produces glabrous or sparsely pubescent stems that grow horizontally on the water or on the mud, rooting at nodes and producing white spongy roots; the leaves are glabrous and alternate, and have petioles; (2) shoots grow vertically, flowers and stems become pubescent and emerge above the water surface; leaves tend to be more elongate but can vary from lanceolate to elliptical in shape. Flowers are bright golden-yellow with a darker spot at the base. The fruit is a pubescent light-brown capsule containing about 50 seeds.

1.3 ORGANISM DISTRIBUTION

Native range

L. grandiflora is native to the Americas, from the Rio La Plata in Argentina to the southern and eastern United States (Chester and Holt 1990; McGregor et al. 1996). Whereas it primarily occurred in the USA along the Atlantic coast and through the Gulf Coastal Plain, recent reports from California indicate that the range may be expanding as a result of dispersal of vegetative propagules (Okada et al. 2009).

Introduced range

In Europe*, L. grandiflora* is present in the following countries: Belgium (Denys et al., 2004a; Branquart et al. 2010), France (Dutartre et al., 2007), the Netherlands (Kleuver & Hoverda, 1995), Ireland (Caffrey, 2009), Italy (Celesti-Grapow et al., 2009), Spain (Castroviejo et al., 1997), United Kingdom (Newman et al., 2000) and Germany (Nehring & Kolthoff, 2011).

It is also reported in the Eastern part of the United States (Okada et al., 2009; USDA, 2010; Boersma et al., 2006 in DEFRA, 2008) and in Africa in Kenya (Thendi, 1996 in DEFRA, 2008).

Figure 1: Distribution of *Ludwigia grandiflora* in the world.
Green dots: native countries; red dots: introduced countries.
(World map built based on the distribution table data from the Invasive Species Compendium, CABI 2009)

1.4 REASONS FOR PERFORMING RISK ANALYSIS

Ludwigia grandiflora **is a successful invasive aquatic plant species in several European countries. It can easily establish in the wild and produces very dense populations after escaping from ornamental ponds. Detrimental impacts on native flora and fauna by** ***L. grandiflora*** **populations are reported through physical and chemical transformation of the invaded ecosystems in the adventive range.**

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 neighboring 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.

In Belgium, the first occurrence of *Ludwigia grandiflora* in the wild was in Louvain-La-Neuve, Brabant district, in 1983 (Bauchau, 1984). The species is now widespread in Flanders (Figure 2) with 61 stations (IFBL 1km² square) recorded since 1995 in the Flandrian, Brabant and Kempen districts (Flora databank, 2013). 21 stations (IFBL 1km² square) have been recorded since 1984 in Wallonia, but only in the Brabant and Meuse districts (DEMNA, 2013). For the time being, *L. grandiflora* has not been observed in the Maritime, Ardennes and Lorraine districts. Population sizes are variable with a cover ranging from 1 to 100 % of the surface of invaded sites, meaning from less than 1 m² to 3500 m² (Stiers et al., 2011; Delbart, unpublished results).

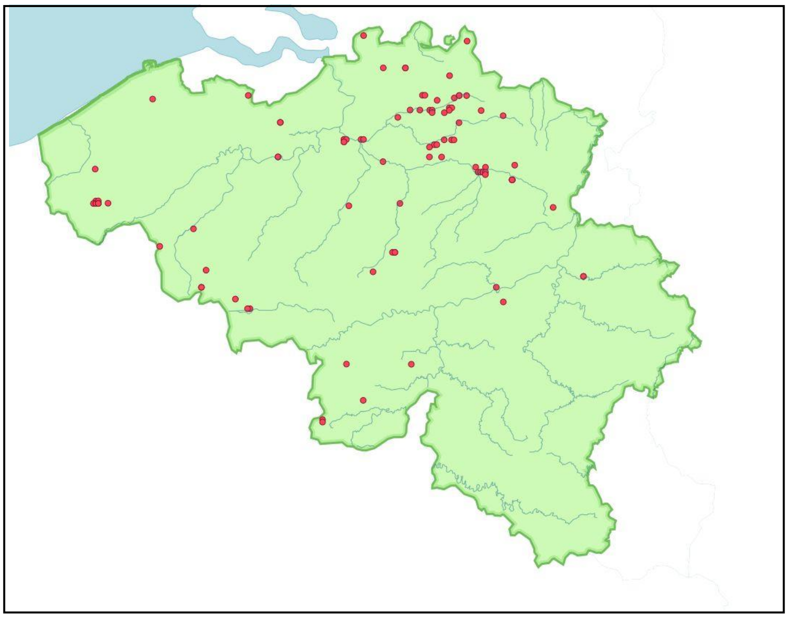

Figure 2- Distribution of *Ludwigia grandiflora* in Belgium
Map built by aggregating occurrence data from the Flora databank (2013) and DEMNA (2013).

2.1.2 Present status in neighbouring countries

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

In France, *L. grandiflora* is widespread in the South and in the West and has recently been observed to spread in northern and central France (Dutartre, 2004a, 2007) under Atlantic climatic conditions (Figure 3). Populations have been observed to survive during the winter despite a more continental climate (Dutartre, 2004b).

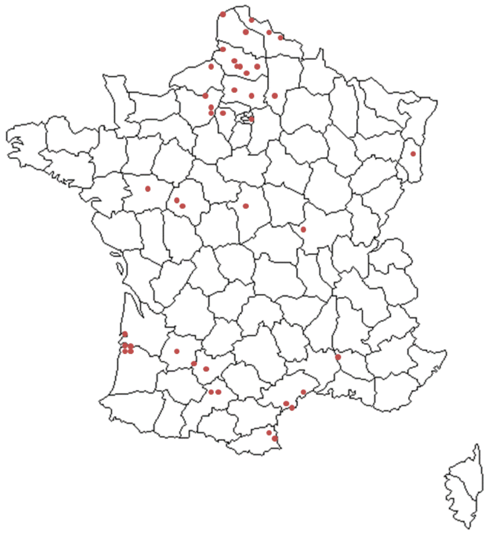

Figure 3- Distribution of *Ludwigia grandiflora* in France

(Map built by aggregating data from the *Flore de la Flandre française* (Toussaint et al., 2008), Levy et al. (2011), and occurrence data from Tela Botanica (2013) (including data from SOPHY, banque de données botaniques et écologiques; Prospection Flore du CEN-LR : données issues des prospections flore du Conservatoire des Espaces Naturels du Languedoc-Roussillon; Carnet en Ligne : données issues des observations publiques du Carnet en Ligne de Tela Botanica; Carré UTM 10x10 km : comportant plusieurs sources de données distinctes).

In the Netherlands, *L. grandiflora* is at an early stage of invasion. It is reported throughout the country except in the Waddensea Islands with varying abundance (Kleuver & Hoverda, 1995; Luijten & Odé, 2007).

In the UK, *L. grandiflora* has been considered as a pest species since the middle of the 1990s (Newman et al., 2000). In 2010, 13 locations had been recorded in England and one in Wales (Williams et al., 2010).

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).

The main introduction pathway for *L. grandiflora* in Belgium is the intentional import as an ornamental aquatic plant for outdoor use in ponds, similar to other European countries (Grillas, 2004). The species is planted and thereafter transfers to semi-natural and natural habitats. Exchanges between gardeners most probably occur in addition to direct and internet sales.

In Belgium, a socio-economic analysis performed in 2010 on invasive ornamental plants assessed that 8% of surveyed nurseries were selling *L. grandiflora* (Halford et al., 2011a). A code of conduct developed by the *Life+* Communication project AlterIAS in 2011encourages signatories to stop selling and using the species (Halford et al., 2011b).

In France, a study of aquatic plants imported in 10 EPPO countries between 2005 and 2007 indicated that *L. grandiflora* was imported as an ornamental plant in April 2006 from Indonesia (100 units) and from Singapore (170 units) (Brunel, 2009). Introduction and sale of *L. grandiflora* are now forbidden by law in France since 2007 (Ministère de l'Ecologie et du Développement durable, 2007). This is also the case in Switzerland within the 'Ordinance on the handling of organisms in the environment' (Federal Authorities of the Swiss Confederation, 2008). From 2010 onwards, the signatories of the Dutch Code of Conduct have committed themselves to stop selling *L. grandiflora* (Ministerie van Landbouw, Natuur en Voedselkwaliteit, 2010).

L. grandiflora can also spread either naturally with water currents or as a result of human activities (shipping, angling, etc.) (Haury et al., 2010). Introduction in Belgium through colonisation from neighbouring areas where the species is established needs to be further considered. Indeed, several populations are known in France close to the border with Belgium (see figure 3), in an area rich in marshes, canals, ponds and lakes (e.g. Marais d'Harchies).

ENTRY IN BELGIUM

Although *L. grandiflora* is regulated in some neighbouring countries, the probability of entry in Belgium by intentional import as an ornamental aquatic plant for outdoors is very likely.

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

Life cycle: *L. grandiflora* shows a high growth rate, and displays several overwintering strategies: seeds, persistent vegetative material. (Dutartre et al., 2007).

Vegetative reproduction: It mainly reproduces through strong vegetative reproduction and can easily regrow from fragments (Dandelot, 2004). Fragments are buoyant and can float away from the parent plants. *L. grandiflora* is able to form new shoots from single nodes or single leaves (Hussner, 2009). As a result, the species exerts intense propagule pressure.

Biomass production can be very fast, with standing crop values reaching over 2 kg of dry matter per m² (Dutartre, 2004b; Pelotte, 2003; Dandelot, 2004).

Sexual reproduction: *L. grandiflora* is an outcrossing plant, pollinated by insects. Germination requires cold stratification. Dandelot (2004) estimated that *L. grandiflora* has a high potential seed output of c. 10 000 seeds per m² (about 40 seeds were produced per fruit (Ruaux et al., 2009) and around 50% were viable (Ruaux, 2008)). Fructification rates however vary greatly from one region to the other. Germination rate is also highly variable between 0 and 85 % depending on laboratory storage conditions (Ruaux, 2008; Touzot & Dutartre, 2001). Germination occurs during the first fifteen days of experiments. The seed bank is considered to be persistent (Ruaux et al., 2009). Recruitment from seed and consequent seedling development has been observed in the field (Dutartre et al., 2007).

Strategy for survival: Adventitious roots allow *Ludwigia* sp. to absorb atmospheric oxygen and thus tolerate anaerobic conditions (Rejmánková, 1992). Hussner (2010) highlighted that *L. grandiflora* reaches maximum relative amounts of roots under drained and low nutrient conditions, while the relative amount of shoots is highest in waterlogged and nutrient-rich conditions. Sexual reproduction is likely an additional mechanism for winter survival and spread of *L. grandiflora*, especially over long distances (Ruaux et al., 2009). However, for the time being, no viable seed was observed in the Belgian populations, which is in opposition with the situation observed in the Netherlands, France and Northwestern and Western Germany (Stiers, Delbart, Hussner, personal communication).

Organism adaptability: *L. grandiflora* has a highly variable morphology depending on abiotic conditions (Lambert et al., 2010), especially regarding leaf shape and stem size. Three morphological forms are distinguished: 1) a prostrate small-leaved form; 2) an actively growing creeping form at initial development or in static or slowly flowing water, and 3) an erect form at later stages, in shallow water with favourable conditions. The plant is mainly aquatic but is also able to colonize damp terrestrial habitats, such as riverbanks or wet meadows. It can grow on nutrient-poor to nutrient-rich soils and sediments (Matrat et al., 2006). An increase in the root:shoot ratio is observed with decreasing nutrient availability, which reveals an adaptation capacity to low nutrient conditions (Hussner, 2009).

B/ Climatic requirements[2]

The species is found in temperate, Atlantic and Mediterranean climates (Dutartre et al., 2007).

There is an evident lack of specific data on the cold tolerance of *L. grandiflora*. Although emergent parts of the plant are killed by frost, submerged, buried parts of the plants and rhizomes are reported to survive the wintertime if they are not enclosed in ice. Historical information illustrates the frost-tolerance of the species: the species was observed to survive

[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.

the winter of 1853-1854 with 53 days of frost and temperatures reaching -12°C around Montpellier in France (Vauthey et al. 2003). Seeds of *L. grandiflora* can survive being frozen. Minimum temperatures allowing germination are currently being assessed (Hussner, pers. comm.).

Hussner (personal communication, 2013) states that climatic tolerance of *L. grandiflora* should not be narrowed down to temperature tolerance. The length of the growth period (which is important for seed development) and whether the climate is more continental or more oceanic (temperature amplitude, humidity,…), are additional important environmental variables. In particular, plants show only a weak stomatal response to increasing vapour pressure deficit (VDP), which might hinder growth in more continental climates (Hussner, personal communication 2013).

In a recent risk mapping exercise using the biogeographical regions defined by the European Environmental Agency, the species was considered as 'established' in the Atlantic climate zones of Belgium, The Netherland and Germany (Figure 4) (Belgian Biodiversity Platform – NOBANIS, 2012).

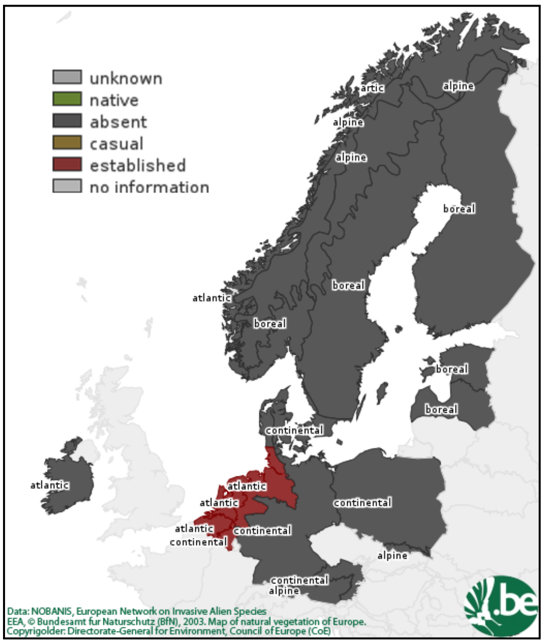

Figure 4 – Risk map of *Ludwigia grandiflora* based on natural vegetation of Europe (EEA). (Belgian Biodiversity Platform – NOBANIS ; http://home.bebif.be/nobanis . Accessed on 10/04/2012)

The main area of origin has a similar climate to Belgium in some parts, but is mostly frost-free. However, *L. grandiflora* has successfully colonised the USA as far north as Washington State and New York State, which have harsher winters than Belgium.

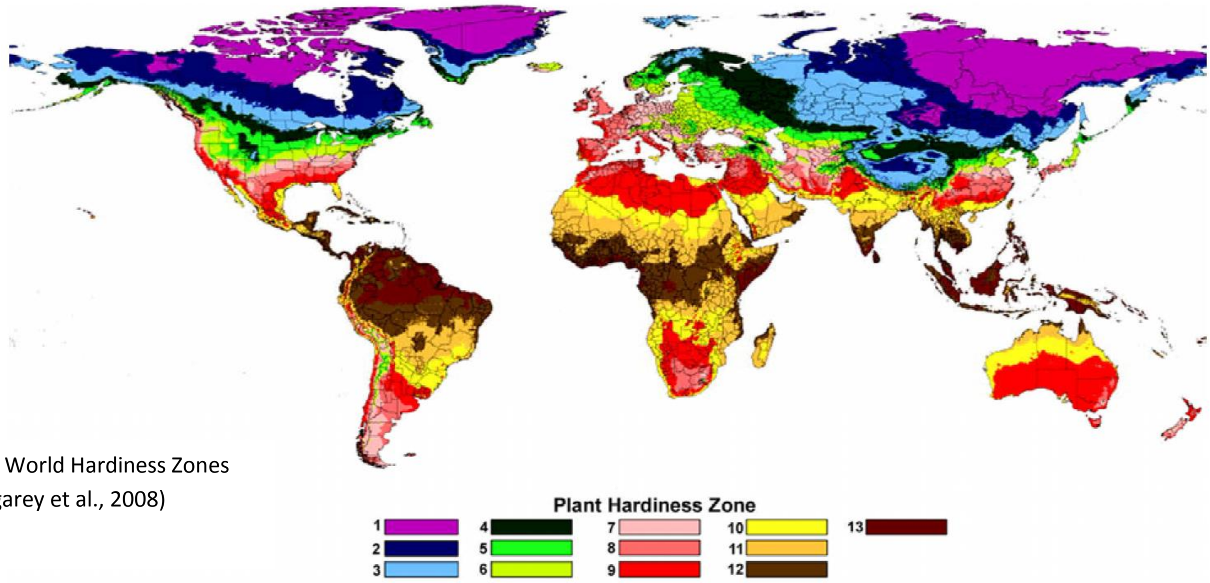

Figure 5 – World Hardiness Zones map (Magarey et al., 2008)

As illustrated on Figure 5, Belgium is covered by the USDA hardiness zones 7 and 8. These zones also encompass several countries from *L. grandiflora* area of origin (see section 1.3). These climatic similarities are also verified when considering the Köpper-Geiger climate classification (figure 6).

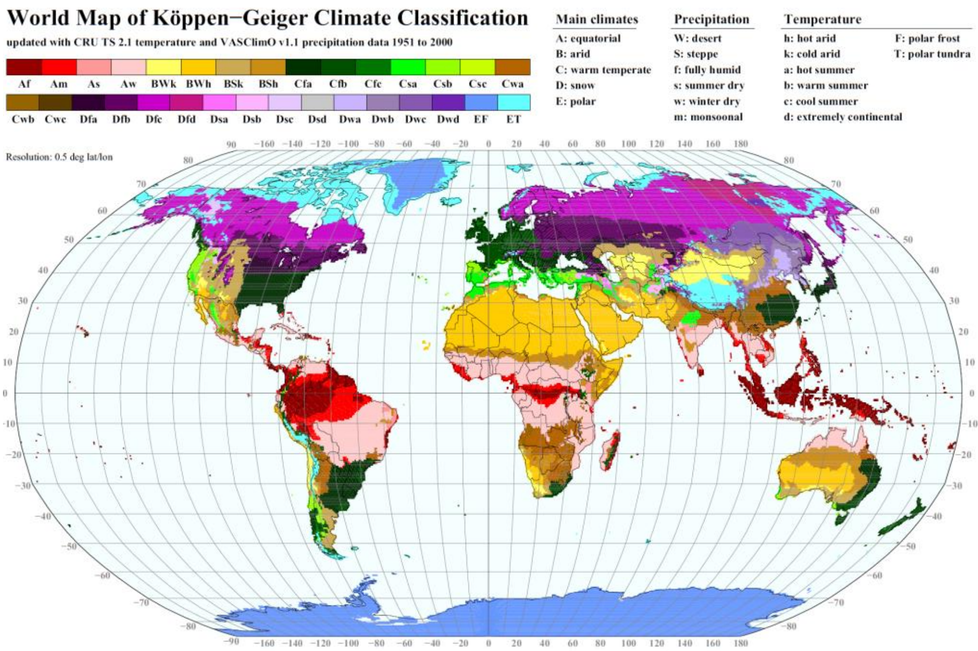

Figure 6 – World Köpper-Geiger climate classification map (Kotten et al., 2006).

C/ Habitat preferences[3]

In its native range, *L. grandiflora* is reported in wetlands, in the transition zone-between aquatic and terrestrial environments (Rolon et al., 2008; Hernandez & Rangel, 2009). It prefers static or slowly flowing waters: rivers, shallow ponds and lakes, canals, oxbow lakes, wet margins of ponds and lakes, wetlands, ditch networks, sediment bars on river borders and wet meadows (Laugareil, 2002; Zotos et al., 2006).

Following the EUNIS Land Cover nomenclature, suitable habitats are: (1) Surface running waters (C2) and Surface standing waters (C1); (2) Inland surface of water bodies (C3); and (3) Seasonally wet and wet grasslands (E3).

An analysis of the distribution of *Ludwigia* spp. in France shows that invaded habitats include at least 12 habitats concerned by the European Habitat Directive 92/43/EEC (3110-1; 3130; 3140; 3150; 3250; 3260; 3270; 3280; 3290; 91EEO 44.3,44.4,44.13; 6430-4 and 7210), and 3 additional types of wet habitats: aquatic vegetations of the *Nymphaeion albae*, swamp vegetations with tall helophytes, prairial vegetations and flooded forests (Dutartre et al., 2007).

L. grandiflora tolerates a wide range of conditions in terms of nutrient level, type of substrate, pH and water quality (Matrat et al., 2006; Stiers et al., 2011). It is mainly observed in full light but tolerates shade (with a reduced biomass), while it is limited by flow velocity (greater than 0.25 m/s) (Dandelot, 2004) and higher salinity (Thouvenot et al., 2012). Its growth is promoted by high nutrient conditions (Hussner, 2009; 2010), promoting dominance (Rejmánková, 1992). The Relative Growth Rate (RGR) reported experimentally reaches up to 0.060 g g^{-1} dry weight day^{-1}, with a minimum of 0.033 g g^{-1} dry weight day^{-1} on a drained surface with low nutrient availability (Hussner, 2009; 2010).

Water quality: The water quality varies greatly depending on the habitat. The following indicative measures have been found in France and Belgium (EPPO, 2011):
O_2: 8 mg/L in summer to 18.3 mg L^{-1} in winter/spring in France, 5-12mg L^{-1} in summer; 9-12 mg L^{-1} in winter/spring in Belgium. Observed pH values: 6.2-9. The plant develops in acid, alkaline, siliceous and calcareous substrates. Conductivity: references provide values comprised between 120 and 968 µS cm^{-1} (Pellote, 2003; Dandelot, 2004; Stiers et al., 2011). Orthophosphates: 0.01-1.065 mgL^{-1} (Charbonnier, 1999; Pelotte, 2003; Dandelot, 2004). The species may grow in water with nitrates concentrations from 0.01 mg L^{-1}. Total phosphorous: 0.02-0.632 mg L^{-1} (Stiers et al., 2011; Charbonnier, 1999; Pelotte, 2003). Permanganate Index (oxidizing organic and inorganic matters in mg l^{-1} O_2): 2 – 55 in acid lakes and ponds. Ammonium (NH_4): 0.004-0.091 mgL^{-1} (Stiers et al., 2011). Chlorophyll a: 5.1-186.9 µg L^{-1} (Stiers et al., 2011).

Sediments: Biomass production is positively correlated with concentration of organic matter and nitrogen (Charbonnier, 1999; Pelotte, 2003). The lower the nutrient concentrations in the sediment, the higher the root:shoot ratio (Hussner, 2009). Observed concentrations of

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

organic matter vary from 2 % in sand up to 22 % in muds on lake and pond banks (Pellote, 2003) and low phosphorus and nitrogen concentrations are recorded in interstitial water.

Physical characteristics of waterbody: L. grandiflora colonizes lake shores up to 0.8 m above the mean water surface and can grow in 3 m deep waters (Dutartre, 1986; Lambert et al., 2009a). Optimal conditions for growth are between – 0.7 m and + 0.3 m (above mean water surface level) (Dutartre et al., 2007). Sediment types are: mud, sand, gravel, clay and peat. Colonization occurs in both permanent and temporary humid areas, as well as in ponds regularly drained (Dutartre et al., 2007).

Water flow velocity: Optimal habitats are static or slow-flowing waters (Charbonnier, 1999; Dandelot, 2004; Pelotte, 2003). However, Dutartre et al. (2007) point to the presence in low numbers of this species in sub-optimal habitats. Although these populations are negligible in terms of the total regional population size, they may be important at the dispersal front. In particular, isolated individuals may occur and sustain in micro-habitats of dynamic waters without winter floods.

Salinity : L. grandiflora is not usually found in brackish waters (Grillas et al., 1992; Thouvenot et al., 2012).

D/ Food habits[4]

Irrelevant

E/ Control agents

The beetle *Altica lythri* Aubé (Chrysomelidae) eats leaves of *Ludwigia* in the South-West of France (Petelczyc et al., 2006). Two coleopterans of the genus *Galerucella* have also been observed to feed on leaves of *Ludwigia* spp. (Dauphin, 1996). Observations indicates that the Louisiana crayfish (*Procambarus clarkii*) and the coypu (*Myocastor coypus*), two exotic species, can eat large amounts of *Ludwigia* spp. (Lambert et al., 2009a), generating fragments thus increasing the spread of *L. grandiflora*. Cattle may eat *Ludwigia* spp. in shallow waters in summer when food availability is low. Horses have also been recorded to feed rarely on *Ludwigia* spp. in the French Camargue (Legrand, 2002).

These observations remain, however, anecdotal as animals usually avoid eating plants containing saponins, as is the case with *L. grandiflora*. The observed control agents do not prevent establishment and development of *L. grandiflora*.

F/ Establishment capacity in Belgium

L. grandiflora presents a suite of characteristics typical of successful invasive plant species, among others a large native range, a high dispersal capacity, a wide habitat tolerance, an

[4] For animal species only.

important vegetative potential, mechanisms allowing to overcome the winter period and high adaptative ability.

The potential for further establishment of *L. grandiflora* is therefore considered to be very high in Belgium as convenient habitats are widely available within the area. Further information concerning the climatic limitations should help to specify the establishment capacity of the species in areas characterized by low winter temperatures.

G/ Endangered areas in Belgium

In Belgium, Endangered N2000 Habitats potentially at risk are the following : (1) 3130 - Oligotrophic to mesotrophic standing waters with, vegetation of the *Littorelletea uniflorae* and/or *Isoeto-Nanojuncetea;* (2) 3150 - Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition* - type vegetation; (3) 3260 - Water courses of plain to montain levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* Vegetation; and (4) Rivers with muddy banks with *Chenopodion rubri* p.p. and *Bidention* p.p. vegetation (Branquart *et al*., 2010).

When performing the pest risk analysis at the EPPO level, experts used the CLIMEX model to predict the potential geographical distribution of *L. grandiflora* on the basis of the current distribution of the species (EPPO 2011b). The resulting map is only indicative of the potential distribution of the species because data on cold tolerance of *L. grandiflora* are lacking *(see previously section 2.2.4)*. It is possible that the species could establish in countries with more continental climates. Because of the early stage of some invasions (e.g. in Ireland and Germany) (Nehring and Kolthoff, 2011), it is not possible to use climate data for the current range to predict the entire area at risk. Belgium was however included entirely in the range at high risk of the CLIMEX map produced by EPPO (2011b).

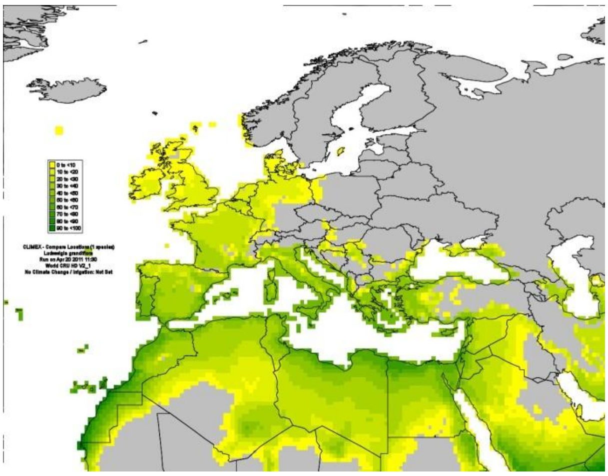

Figure 7 – CLIMEX map of *L. grandiflora* (EPPO 2011b)

Estimation of risk areas in The Netherlands indicate that all shallow slow flowing and still water of the territory were potentially at risk *(EUPHRESCO-DeCLAIM, 2011).*

Considering the comments of Hussner (personal communication 2013) mentioned above concerning the frost resistance of rhizomes and seeds, climatic conditions in the Belgian Ardennes and Lorraine are believed not to limit the presence of *L. grandiflora* in this area.

Current establishment capacity in the Belgian geographic districts:

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

ESTABLISHMENT CAPACITY AND ENDANGERED AREAS IN BELGIUM

Despite the very limited information available on thermal requirements, *Ludwigia grandiflora* is likely to further establish self-sustaining populations in most of Belgium. The species is indeed well established in neighbouring areas presenting similar climatic conditions. Appropriate habitats are present in the Belgian territory and include high value habitats; Natural enemies present in Europe are at present unlikely to affect the invasiveness of the species.

2.1.4 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

Within a catchment, the dispersal capacity of *L. grandiflora* is important as vegetative fragments are known to be dispersed by water flow (from 40 to 881 cuttings recorded daily on a 10 m wide water way) (Legrand, 2002), and by animals (e.g. fragments can be dispersed by coypu (*Myocastor coypus*) according to Haury et al. (2009)). Fruits of *L. grandiflora* can also spread easily by flowing water due to their high buoyancy (Ruaux et al., 2009). Fruit

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

buoyancy was recorded to last more than 3 months in the Loire River (Ruaux, 2008). In static waters, long-term buoyancy is also advantageous for dispersal because occasional water movement (through winds, currents, animals, etc.) increases the establishment elsewhere within lakes and ponds. According to Dandelot (2004), seedlings produced by fertile populations are also dispersed by water. She reports that in France, *Ludwigia* spp. are mainly found downstream in coastal rivers due to torrential floods characterizing Mediterranean rivers, progressively displacing populations of *Ludwigia* spp. toward river mouths. It is assumed that most populations in flowing waters would originate from ponds and riverside areas that are only occasionally connected by flood events.

Some examples of local proliferation and dispersal are documented in France: in the Marais d'Orx (South-West of France), *L. grandiflora* spread over 128 ha in 6 years (Saint Macary, 1998). The Turc pond (Landes) was covered for 3 hectares in about 10 years (Dutartre, 2004b). In the Marais Poitevin (West of France), it has spread over 500 km of a river and ditch system in 16 years (Dutartre et al., 2008).

Between catchments, natural spread between unconnected water bodies is poorly understood. The species may be spread by waterfowl, but there does not seem to be any concrete observation of this.

B/ Human assistance

L. grandiflora is an appreciated ornamental, making human-mediated dispersal of *L. glandulifera* one of the most important dispersal pathways, especially over long distance. The more the species is traded, the higher the probability of the species to escape from cultivation and to establish new populations. Trade of *L. grandiflora* is common in Belgium (8% of nurseries (Halford et al., 2011a)).

Deliberate planting in the wild has been reported in France (A. Dutartre, CEMAGREF, pers. comm., 2010 *in* EPPO, 2011).

Management practices can also increase dispersal of the species: maintenance works (dredging, mowing,…) produce viable plant fragments that can be spread by water currents or human activities (Dutartre, 2004b). Direct connection of infested and non-infested sites and improper management practices contribute to the spread of the species in these systems. The species could also be spread by machinery (Dutartre, 2004b; Dutartre 2007).

Accidental transport through recreational activities (boating, fishing) is not documented, but is considered as a possible cause of spread within and between catchments: stem fragments can survive two days out of the water, even much longer when emergent, and may be accidently transported from a colonised site to another (Dutartre et al, 2007).

DISPERSAL CAPACITY

***Ludwigia grandiflora* can easily disperse both naturally and with human assistance from cultivation ponds. It shows a high dispersal rate through vegetative fragments within a catchment, providing that suitable habitats are present. Human activities are principally responsible for long distance transport, with zoochory potentially contributing as well.**

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.

A/ Competition

Several studies have focused on the competitive capacity of *L. grandiflora* both in experimental or in natural conditions.

In France, the dominance of *Ludwigia* spp. leads to local loss of floral diversity (Dandelot, 2004). In several ponds in the Landes region (South-West of France), decreases of *Potamogeton natans*[6]*, *Myriophyllum spicatum**, *Iris pseudacorus** and *Ludwigia palustris** have been observed as a consequence of competition with *L. grandiflora* and *Lagarosiphon major* (Dutartre, 2002). Based on floristic analyses in different areas of a marsh colonized by *L. grandiflora* in Brittany, Haury et al. (2009) showed that, in similar conditions, *L. grandiflora* outcompetes *Phalaris arundinacea**, *Glyceria maxima**, *Phragmites australis** and *Polygonum hydropiper**. They also recorded an overall reduced number of species. On the Loire river, impacts on species richness and structure of invaded communities varied with the type of habitat: no significant effect was reported within the river (aquatic habitat) whereas on the river borders that become drier, species richness and diversity of communities were negatively correlated with the abundance of *L. grandiflora* (Ruaux, 2008). Cover percentages of *Ludwigia* spp. were generally high and only few other species with limited cover occurred.
In Belgian ponds, large mats of *L. grandiflora* cause a reduction in native plant species richness. A difference of 70% was observed between uninvaded and heavily invaded plots.

[6] Species with an asterisk are also present in and native to Belgium

The submerged vegetation was most vulnerable. Significant changes in native species abundance following invasion were found for the submerged *Ceratophyllum demersum* and the emergent *Alisma plantago-aquatica* and *Lycopus europaeus* (Stiers et al., 2011).

An allelopathic interaction of *L. grandiflora* was experimentally demonstrated with *Lactuca sativa* and *Nasturtium officinale** through decreased germination, increased mortality of seedlings, disturbance of seedling elongation and seedling chlorosis (Dandelot et al., 2008).

Recently, Thouvenot et al (*in press*) have shown experimentally that the competitive strategy of *L. grandiflora* differs according to growth form (submerged *vs.* emergent) and its density. *L. grandiflora* density was also altered by the presence and the density of neighbouring species. The same work indicated that *L. grandiflora* might facilitate the establishment of other exotic species, in particular *Egeria densa*, in accordance with the 'invasional meltdown hypothesis' (Simberloff & Von Holle 1999). Concerning competition with other species in the same experiments, *L. grandiflora* seemed to have little impact on the native species *Ceratophyllum demersum** and *Mentha aquatica**. This appears to contradict field observations (see Stiers et al. 2011).

During the EUPHRESCO DeCLAIM project, simulations of the growth of *L. grandiflora* were performed based on the CHARISMA model (individual-based and spatially explicit model; van Nes et al., 2003), with two competing species, *Chara aspera* and *Potamogeton pectinatus** over a 10 year period. The results indicate that *L. grandiflora* would outcompete the two species and dominate the macrophyte community after a few years, if left unmanaged (EUPHRESCO DeCLAIM, 2011).

Besides competition with other plant species, the presence of *L. grandiflora* has been associated in some ecosystems with a reduction of macroinvertebrates and fish (Grillas et al., 1992; Dutartre et al., 1997; Dandelot 2004). One reason might be that dense populations of *Ludwigia* spp. constitute a barrier for the movement of the fish (Legrand, 2002) and may promote hypoxic conditions inducing fish kills and loss of invertebrate diversity (van de Meutter, personal communication 2013). In Belgium, Stiers et al. (2011) demonstrated that uninvaded ponds support a more distinct invertebrate community, including species (e.g. Ephemeroptera) that are rare or missing in ponds invaded by *L. grandiflora*. In the mud below *L. grandiflora* , dipterans of the genus *Chironomus* and naidid oligochaetes tolerant of oxygen stress were common . Preliminary observations also show that *L. grandiflora* is not only integrated in the native plant-pollinator network but shows a dominance in terms of frequency of pollinator visits (I. Stiers, Vrije Universiteit Brussel, unpublished results).

B/ Herbivory

Irrelevant

C/ Genetic effects and hybridization

There is no scientific information available on potential hybridization including *L. grandiflora* and any native species in the adventives range. It is however worth noting that *L. palustris* (L.) S. Elliott is a congeneric species present in Belgium (Flanders).

D/ Pathogen pollution

Irrelevant

E/ Effects on ecosystem functions

Effects of Ludwigia spp. on ecosystems functions proceed from changes of ecological processes and structures in various ways. First, the high biomass production leads to reduced water flow (Dutartre, 1988) in channels, ditches and shallow rivers. This causes increased sedimentation, which leads to higher flood risk.Plant and animal communities change, including fish disappearing from dense beds (Dutartre, 2007). In standing open waters, the slow litter decomposition induces shallowing and succession to swamp and marsh vegetation. The allelopathic compounds released in the water contribute to alter ecosystem processes and are expected to affect different kinds of organisms (Dandelot et al., 2008; Dutartre, 2007).

In static waters, dense stands reduce gas exchange between water and atmosphere and light availability for submerged plants. Consumption of oxygen by root respiration of *Ludwigia* spp. and decomposition of litter result in severe deoxygenation which is harmful to aquatic fauna. Oxygen concentrations inferior to 1 mg/L have been recorded underneath *L. grandiflora* mats (Dandelot et al., 2005a). A decrease in pH is also commonly observed due to the lack of photosynthesis below the water surface (Dandelot et al., 2005b).

ENVIRONMENTAL IMPACTS

***L. grandiflora* develops quickly and produces/forms very thick monospecific floating carpets/mats at the surface of water bodies. This alters the physical-chemical water quality (reduction of light and dissolved oxygen). Allelopathy reduces the germination and survival rates of other plant species and contributes to the significant changes of ecosystem processes. The species outcompetes most native water plants and creates an anoxic environment detrimental to many plant and animal species. *L. grandiflora* is therefore considered as a transformer species according to Richardson et al. (2000).**

Further establishment of *Ludwigia grandiflora* in Belgium will consequently result in important environmental changes through alteration of both plant and animal communities in invaded habitats, as well as extensive transformation of invaded ecosystem processes and functions. Hybridization with native congeneric species seems unlikely.

2.2.2 Other impacts

A/ Economic impacts

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

In general, studies use documented financial costs as proxies for underlying IAS economic impacts (Oreska & Aldridge, 2011). Mostly, very few ecological impacts are considered in the general cost estimates as they cannot be monetized. To this end, the use of the ecosystem services approach might help to assess overall economic impacts better, including social impacts. This issue is however only emerging and no concrete information on the impact of *L. grandiflora* on ecosystem services could be traced.

Damages to infrastructure

The GB non-native Organism risk assessment performed on *Ludwigia* species reports that these species are problematic in irrigation channels, dams/reservoirs and canals and rivers (Non Native Species Secretariat, 2011). The floating mats can be colonised by other plants (sedges, grasses and later shrubs and trees). Floating islands can be created which could pose serious flood risk issues in the man-made landscapes (Dandelot, 2004). No information concerning the monetary costs linked to damages to infrastructure was found.

Impact on pastures

Impacts on pastures (crop yields and/or quality) seem restricted to loss of grazing areas in wet meadows (Dutartre et al., 2007). *L. grandiflora* outcompetes wetland grasses and therefore reduces grazing capacity for livestock in these habitats (Dutartre, 2004a). The species has a low palatability (cattle and horses only eat the plant when no other species are available). In France, this loss consequently impedes some farmers to get agri-environmental financial incentives developed in the framework of the Common Agricultural Policy, but no information concerning the monetary costs associated to this impact on pastures was found. To our knowledge in Belgium, there is no evidence of similar impacts on pastures, probably because of the limited invasion of *L. grandiflora* in pastures to date (Delescaille, personal communication 2013).

Control costs

Generalizations of control costs are always difficult as they depend on the intensity of invasion, the accessibility of invaded sites and the selected techniques. Cost examples from different countries are presented below:

- In Belgium, De Bruyn *et al.* (2007) indicated that about 272.000 € in 2005 and about 140,000 euros in 2006 were necessary to manage respectively 136.000 m^2 and 114.000 m^2 invaded by three aquatic species, among which *L. grandiflora*.
- The city of Yper has been investing in the control of *L. grandiflora* for the last ten years. The plants are manually removed as much as possible with the roots. They are then transported

to a composting area. The work is done partly by a private company and the city services. In 2011, 170 hours man-made were charged with a cost (including VAT) amounted to 2407 €. In 2012, the values reached 251 hours man-made with a cost of 3566 €. Additional costs for the removal of plant material (made by the city services) and the compost treatment is estimated at 500 € per year (Stubbe 2013, personal communication). These 10 years of control have prevented the invasion of large water bodies but have not allowed eradication.

- In Western France the cost recorded per ton of fresh biomass between 1990 and 2003 for both *L. grandiflora* and *L. peploides* (Million, 2004) are: 51 to 64 € for highly invaded sites with very dense biomass using mechanical removal techniques and 1100 to 1330 € for new infestations, for removal of small isolated patches over larger areas using manual removal techniques and follow-up after initial mechanical extraction.
- In Great Britain, based on information gathered from surveyed stakeholders, Oreska & Aldridge (2009) estimated the annual reported control cost for *L. grandiflora* to be on average 11900 € per locality (£10.263), without regard to average surface areas of localities.
- Considering 13 sites in England and Wales in 2010, Williams et al. (2010) estimated the total cost of eradicating the outbreaks of *Ludwigia* species at 85,059 € (£73,351), including additional costs related to regular follow-up treatment and assuming that this would be similar as for *Hydrocotyle ranunculoides*. Costs for a single attempt of widespread eradication action from wetlands were assessed at a total cost for England, Wales and Scotland to 93135985 € (£80.365.852). As more than a single action would often be required, the costs of complete eradication would be higher (at least double).
- In California, the cost of mechanical removal from two wetlands varied between US$3017 and US$ 9682 per ha according to the habitat type while the cost of chemical control varied between US$1313 and US$4377 per ha (McNabb and Meisler 2006).

B/ Social impacts

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

Stands of *Ludwigia* spp. can be very dense, forming several metres long floating islands preventing activities such as angling, boating or hunting (Menozzi, 2005). When such level of proliferation is reached, *L. grandiflora* ceases to be acceptable visually for the public although the flowers are often appreciated (Dutartre et al., 2007). Another social impact may be the increased risk of flooding (Dandelot, 2004).

In some cases, floating mats may increase mosquito populations by creating static water and preventing predators from reaching the larvae and hamper control efforts (e.g. Laguna de Santa Rosa in California; Meisler, 2008). With the spread of the West Nile Virus to Sonoma County, California, reduced mosquito control is perceived as a public health threat in this area.

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.

The number of populations of *L. grandiflora* in ornamental ponds is unknown in Belgium. However, considering that the species is currently sold by 8% of ornamental professionals, its presence in gardens is assumed to be considerable.
Since *L. grandiflora* populations occur in neighbouring countries, its entry in Belgium by natural spread or human assistance is likely to occur in forthcoming years, e.g. from nearby hydrologically connected sites in Northern France.

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.

Different initiatives have been launched to limit secondary introduction of *L. grandiflora*. Although the species is already established at a considerable number of locations in Belgium, preventive measures can help to reduce propagule pressure and limit colonization events, in particular in high biological value habitats.

(i) Prohibition of organism importation, trade and cultivation

To date, import, trade and cultivation of *L. grandiflora* are not prohibited in Belgium. Strong restrictions would contribute to limit establishment in areas where the species is still absent.

L. grandiflora is included on the list of species that should not be sold or planted of the voluntary 'Belgian Code of conduct on invasive plant species' for horticultural professionals and related stakeholders (Halford et al. 2011b). This code of conduct was elaborated in the European *Life+* information and communication project "AlterIAS" (ALTERnative to Invasive Alien Species) launched in 2010. Among others, it also proposes native alternatives to invasive species (Mathys et al., 2012), in this particular particular *Caltha palustris*, *Ranunculus aquatilis or Sagittaria sagittifolia*.

From 2011, a Ministerial Decree considers three aquatic invasive plants in Flanders, including *L. grandiflora*. This forbids to sell, exchange or buy the species from January 2011 onwards. This is also the case in the Brussels Region, selling, since March 2012 (Ordonnance relative à la Conservation de la Nature, 2012). These laws provide the basis for preventive actions, control and eradication. In the Brussels Region, such actions require an advice of the Council for the Environment and the Brussels High Council for Nature Conservation (Art. 78).

Initiative concerning a ban on trade or voluntary actions have also been taken in other European countries. Introduction and sale of *L. grandiflora* are now forbidden by law in France since 2007 (Ministère de l'Ecologie et du Développement durable, 2007). This is also the case in Switzerland within the ordinance on the handling of organisms in the environment (Federal Authorities of the Swiss Confederation, 2008). From 2011 onwards, the signatories of the Dutch Code of Conduct have committed themselves to stop selling *L. grandiflora* (Ministerie van Landbouw, Natuur en Voedselkwaliteit, 2010). It was signed by the "Unie van Waterschappen" on behalf of local water boards of the Netherlands, the Ministry of Agriculture, Nature and Food safety, and umbrella organisations representing producers, importers, retailers and garden centres.

As *L. grandiflora* occurs at the border of the national territory, it is also a Belgian responsibility to take actions to prevent the species to spread naturally to adjacent countries.

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

Requiring specific conditions for cultivation is not useful for *L. grandiflora* as the species can escape from ornamental ponds.

In the Brussels Region, the intentional introduction of *L. grandiflora* in the wild is already forbidden by law from March 2012 (Ordonnance relative à la Conservation de la Nature, 2012, annex IV). In Wallonia, a general interdiction on releasing species into the wild is in force with the Decree on Nature Conservation (Loi sur la conservation de la Nature – Wallex 1973). Moreover, the Government adopted a general action plan in 2007 in order to include social and environmental perspectives in public calls (Circulaire relative aux espèces exotiques envahissantes - Wallex 2009). Specifications forbid the intentional introduction of invasive species that are listed on the alert and black lists of exotic species of the Belgian Information system on invasive alien species *Harmonia* (www.ias.biodiversity.be). *L. grandiflora* belongs to the black list and is therefore concerned by this regional law. This circular is currently under revision.

The effects of these regulations on *L. grandiflora* populations in the wild are not known so far.

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)?

L. grandiflora is able to develop populations from a single vegetative fragment (Dandelot, 2004; Hussner 2009). Early detection and eradication are therefore essential to prevent further establishment.

However, the species may be difficult to distinguish, particularly in the absence of flowers, which is often the case at the beginning of invasion. This might hamper efficient detection. Training of field workers should help to detect the establishment of new populations in the future and act as early as possible. However, many brochures, flyers, web sites, etc. have drawn attention to this species and anyone with basic floristic skills should be able to recognize it in a vegetative state (Denys, personal communication 2013).

A pilot project *Surveillance, early warning and rapid response* financed by 'Agentshap voor Natuur en Bos' was recently initiated in Belgium in cooperation with the 'Instituut voor Natuur en Bos Onderzoeek' and 'Natuurpunt' (waarnemingen.be and observations.be). *L. grandiflora* was chosen as species of concern for this pilot project.

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

Several research programs have been undertaken to identify efficient management techniques to control or eradicate *Ludwigia* species. These studies often do not make a distinction between *L. grandiflora* and *L. peploides,* assuming that what works for one species will also work for the other (considering their very similar ecology). Management perspectives are therefore often presented for *Ludwigia* sp. as such.

Eradication by applying herbicides is often proposed as an effective method to remove *Ludwigia sp.*, while mechanical and hand removal techniques are recommended for mid- and long term follow-up actions. Timing and method of effective herbicide application vary with habitat type (Kelly and Maguire, 2009). Best management practices also require that all vegetation removed should be handled with care, not allowing it to spread further or reestablish. Care must be taken not to inadvertently spread fragments or seeds attached to clothing or equipment as this is a well-known vector of aquatic invasive species (Dutartre, 2004b; Dutartre, 2007).

However, the use of herbicides is regulated in Europe as only some substances are authorized for use. In Belgium, the use of herbicides is regulated by the Regions and is particularly restricted along ware courses, ponds and catchment areas, as well as in protected areas such as N2000 sites or nature reserves. Specific permission of use exists for some pest species such as nettles, thistles and docks but this should be further investigated for invasive species.

A combination of mechanical, chemical and environmental control options seems to be the best way to control the species and is therefore recommended as best practice (Kelly & Maguire, 2009).

Chemical techniques

In Venezuela, the use of the herbicide halosulfuron-methyl allowed to control more than 80% of *Ludwigia* sp. stands present in rice fields (Suárez et al., 2004).

In California, a combination of herbicides (glyphosate and triclopyr) followed by mechanical removal of biomass was tested to control *Ludwigia sp.* in a channel and floodplain system. (Meisler, 2008). The results varied considerably between sites and were strongly influenced by water depth and the ability to remove treated vegetation. This study concluded that treating dense *Ludwigia* mats can improve water quality, but that decaying biomass should be removed to avoid a critical decrease in dissolved oxygen.

In the UK, attempts to eradicate *Ludwigia peploides* were performed after treatment with various herbicide mixtures (DEFRA 2006). A reduction of 75% was achieved using glyphosate and glyphosate + 2,4 D amine mixtures, and a reduction by 98% was achieved using glyphosate with a non-oil soya sticking agent (probably as a result of prolonged slow release of the herbicide into the plant). The non-oil soya sticking agent was not yet registered for use in Europe in 2007. The report of this study did not mention anything on non-desired side effects on native species.

Mechanical control

Mechanical techniques consist of physically removing plant material or inhibiting growth and development. The different options are manual removal, mechanical cutting or harvesting, chaining or netting (Kelly and Maguire, 2009). Hand pulling is often done for seedlings but very difficult for mature plants as vegetative regeneration allows re-growth from any remaining roots. Hand removing is however convenient for a final finish after other treatments or the follow-up (Williams et al., 2010). Rubber flanges and nets are frequently used to restrain the drift of free floating material, allowing the water to pass through.

In France, many control actions were performed using mechanical techniques. The results are again variable according to site accessibility and invasion level (Dutartre 2004a; Grillas 2004; Gavory & Toussaint 20004).

Environmental control

Shading (including planting of trees along banks) is often described as a potential tool for controlling small infestations. For larger sites, shading may negatively impact other plant species and fauna (DEFRA, 2006). To our knowledge, the efficiency of shading actions has not been assessed so far.

Draining of water bodies has been undertaken in Mediterranean areas with varying success (Grillas 2004): in some sites, the species seems to be eradicated while in other, plants are still present (the latter showing prostrated morphology, reduced biomass and very few flowers). In case of flooding, the dynamics of invasion would certainly benefit from these remaining individuals. In the same ecosystems, the temporary dry out of water bodies induced an increase in salt concentrations. Thouvenot et al (2012) recently demonstrated experimentally that increased salt levels induce a decline in growth and photosynthetic activity in *L. grandiflora*. Salt concentration and dry conditions might therefore act in synergy to limit *Ludwigia* in such habitats.

During the INVEXO project, different methods were tested with varying success (Invexo, 2013). Burning of aerial parts and frequent hand pulling were the most promising methods whatever the level of infestation. Draining, silt pulling out and bank excavation were comparatively less efficient.

<u>Biological control</u>

The flea beetle, *Lysathia ludoviciana*, was found to infest *L. grandiflora* in Alabama, suggesting that the species might be a good candidate for biological control in the introduced area (McGregor et al., 1996).

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

Unless the management technique chosen is highly species specific (such as biocontrol or hand-pulling), any action undertaken to control *L. grandiflora* is likely to affect the native flora and fauna. This is particularly relevant for chemical control techniques which are well known to have negative impacts on the different trophic levels of aquatic ecosystems.

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

As stated above, early detection of *L. grandiflora* is not always easy. However, some eradication actions were successful. In Switzerland, individuals were found in a pond near Geneva (Laconnex) in 2002 (Vauthey et al., 2003). Four separate plots of *L. grandiflora* occupied *s*ome 120 m². The plants were removed manually in 2002 and 2003 and incinerated. Subsequent monitoring did not show any further observation (GREN Biologie Appliquée Sarl, 2003 in EPPO 2011b). Eradication thus seems feasible at an early stage of invasion.

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

Eradication of *L. grandiflora* is very difficult or even impossible in water bodies with heavy infestation. In the French territory as a whole, eradication is not possible anymore (EPPO 2011b). Ancrenaz & Dutartre (2002) reported that only 14 out of 364 management actions seemed to have resulted in a significant population decrease of *Ludwigia* spp. Of these 14 sites, some were suspect of having unfavourable climatic conditions for development of the species.

The species cannot be easily contained or limited to an acceptable population level. Considering the connectivity of many aquatic habitats, and the very high propagule pressure (from fragments and seeds!), efficient containment might be difficult. Even for unconnected ponds, natural dispersal through zoochory is still to be considered.

CONCLUSION OF THE RISK MANAGEMENT SECTION

The prohibition of *Ludwigia grandiflora* import, trade and exchange is considered as an efficient measure for reducing further establishment of the species into the wild, coupled with communication and voluntary actions such as codes of conducts in order to reduce propagule pressure.
As the species is already present in a large part of Belgium, prevention, early detection and populations control should be used complementarily to limit further invasion, in particular in high biological value habitats. This is particularly important considering that large scale eradication programs seem very unlikely to succeed.

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La CiEi est chargée depuis novembre 2009 de coordonner les actions visant à limiter les dommages causés par les espèces invasives en Wallonie. Ses activités se fondent sur l'engagement du Gouvernement wallon à prévenir l'installation de nouvelles espèces invasives et de lutter contre celles dont la prolifération pose problème

http://biodiversite.wallonie.be/invasives
Email : invasives@spw.wallonie.be

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