museum
www.naturalsciences.be

federal public service
HEALTH, FOOD CHAIN SAFETY AND ENVIRONMENT

Risk analysis of the Australian swamp stonecrop, *Crassula helmsii* (Kirk) Cockayne

Risk analysis report of non-native organisms in Belgium

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

Adopted in date of : 11 March 2013

Risk analysis report of non-native organisms in Belgium

Risk analysis of the Australian swamp stonecrop *Crassula helmsii* (Kirk) Cockayne

Henri Robert – René-Marie Lafontaine – Roseline C. Beudels-Jamar – 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 (Instituut voor Natuur- en Bosonderzoek)
Jo Packet (Instituut voor Natuur- en Bosonderzoek)
Arnaud Monty (ULG)
Mathieu Halford (ULG)

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:
Robert, H., Lafontaine, R.-M., Beudels-Jamar, R.C., Delsinne, T. (2013). Risk analysis of the Australian swamp stonecrop *Crassula helmsii* (Kirk) Cockayne. - 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. 37 p.

Contents

Acknowledgements

The authors wish to thank the reviewers who contributed to this risk analysis with valuable comments and additional references: Luc Denys (INBO), Jo Packet (INBO), Arnaud Monty (ULG) and Mathieu Halford (ULG). 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 <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*

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

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

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

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

2. *Risk assessments are advisory and therefore part of the suite of information on which policy decisions are based;*
3. *The risk assessment deals with potential negative (ecological, economic, social) impacts. It is not meant to consider positive impacts associated with the introduction or presence of a species, nor is the purpose of this assessment to perform a cost-benefit analysis in that respect. The latter elements though would be elements of consideration for any policy decision;*
4. *Completed risk assessments are not final and absolute. New scientific evidence may prompt a re-evaluation of the risks and/or a change of policy.*

Photo: Tim Adriaens (INBO)

Executive summary

PROBABILITY OF ESTABLISHMENT AND SPREAD (EXPOSURE)

- Entry in Belgium

The species was first recorded in the wild in Belgium in 1982 and is now established at more than 80 sites. The two main pathways of entry of *C. helmsii* are the trade in horticulture (for ornamental purposes and its characteristics as an "oxygenator" in aquaria and ponds) with subsequent disposal of cultured plants into the wild, and the natural spread from neighbouring countries or existing populations.

- Establishment capacity

Climatic conditions and habitat characteristics of most Belgian water courses, ponds and wetlands fit within the ecological requirements of *C. helmsii*. The species is established in dune slacks, marshes, fens, mires and flood basins, as well as in more permanent waters such as ponds and ditches, as well as on their banks; distribution in or along flowing water is limited, so far. It occurs mostly on mineral soil and in fresh to slightly brackish conditions. *Crassula* being essentially amphibious, most wetlands, streams and ponds (including sensitive areas, nature reserves and Natura2000 sites) are highly vulnerable to *C. helmsii* invasion.

- Dispersion capacity

Main dispersion in the wild is ensured by vegetative propagules, disseminated by water currents, epizoochory and anthropochory. Plants can regrow from the smallest of stem fragments. Human activities can greatly enhance dispersal by disposal of horticultural residues and accidental transport on clothing and footwear, machinery, boats or fishing equipment. In nature reserves, large herbivores can also be an important vector.

EFFECT OF ESTABLISHMENT

- Environmental impacts

C. helmsii forms dense mats on the water surface and in periodically inundated areas. It may also grow entirely as a submersed plant in waters up to 3 deep. It can outcompete certain native plant species and possibly affects natural benthic communities, e.g. by limiting water circulation and changing oxygen regime. The species typically appears in pioneer habitats, e.g. in nature restoration areas where soil has been disturbed by sod cutting. Its presence hampers colonisation of target species and thereby jeopardises investments in nature restoration.

RISK MANAGEMENT

In Belgium *C. helmsii* is available in the horticultural trade and subsequent accidental introduction into the wild is highly likely to occur. Spread from populations in neighbouring countries, though possible, is considered as a minor pathway of entry in our country. Once established, small populations (if detected early enough) can sometimes be controlled. At later stages of invasion, control actions to keep the population to an acceptable level are usually extremely difficult, laborious and costly.

Means of control include manual or mechanical removal of infested sod, which may be combined with prolonged covering with light-blocking material, inundation with salt water and the use of chemicals such as diquat or glyphosate-based herbicides. The use of chemicals for weed control in an aquatic environment is, however, strongly restricted in Belgium. The use of hot organic foam and aquatic dyes as management measure is under investigation. Furthermore, studies on biological control agents are ongoing. Care should be taken not to spread any plant fragments in management. This includes cleaning machinery and carefully laying out transport routes.

A total ban of *C. helmsii* trade and utilization through legal means is desired. In the meantime, promoting a "Code of Conduct" (such as proposed by AlterIAS) for the commercial sector bodies and raising general public awareness on the environmental risks of introducing *C. helmsii* could be beneficial.

Résumé

PROBABILITE D'ETABLISSEMENT ET DE DISSEMINATION (EXPOSITION)

- Introduction en Belgique

Cette espèce a été enregistrée pour la première fois en milieu naturel en Belgique en 1982. Elle est aujourd'hui établie dans plus de 80 sites. Les deux principales voies d'introduction de *C. helmsii* sont le commerce horticole (à des fins ornementales et en raison de ses propriétés oxygénantes dans les aquariums et les étangs) et son élimination subséquente dans la nature (volontaire ou accidentelle) ainsi que sa dissémination naturelle à partir des populations présentes en Belgique ou dans les pays voisins.

- Capacité d'établissement

Les conditions climatiques et édaphiques de la majorité des cours d'eau, étangs et zones humides belges répondent aux besoins écologiques de *C. helmsii*. Cette espèce est établie dans les dépressions dunaires, les marais, les tourbières basses, les tourbières hautes, les bassins d'orage, ainsi que dans les eaux plus permanentes comme les étangs et les fossés et les cours d'eau. On la trouve surtout sur des sols minéraux et dans des conditions d'eau douce ou légèrement saumâtre. *Crassula helmsii* étant essentiellement une espèce amphibie, la majorité des zones humides, des cours d'eau et des étangs (y compris les zones sensibles, les réserves naturelles et les sites Natura 2000) sont très vulnérables à l'envahissement par *C. helmsii*.

- Capacité de dispersion

La dispersion dans la nature est essentiellement assurée par dissémination des propagules végétatives dans les eaux vives et par épizoochorie. De nouveaux individus peuvent se développer à partir d'un infime fragment de tige. Les activités humaines peuvent largement favoriser la dispersion de la plante lors, par exemple, de l'élimination de déchets horticoles ou le transport accidentel sur les vêtements et les chaussures, les machines, les bateaux ou certains équipements de pêche. Dans les réserves naturelles, les grands herbivores peuvent également jouer un rôle important en tant que vecteur.

EFFET DE L'ETABLISSEMENT

- Impacts environnementaux

C. helmsii forme des tapis denses à la surface de l'eau entraînant une compétition avec de nombreuses espèces natives et pouvant avoir un effet très négatif sur les communautés benthiques (batraciens, poissons, invertébrés et diatomées) en limitant la circulation de l'eau et la pénétration de la lumière mais aussi en diminuant la concentration en oxygène dissout. Elle peut se développer jusqu'à 3 mètres de profondeur et présente les caractéristiques

d'une espèce pionnière pouvant se développer rapidement sur des sols perturbés comme cela peut être le cas, par exemple, dans les zones naturelles en restauration. La présence de *C. helmsii* ralenti la colonisation du milieu par d'autres espèces et peut mettre en péril tout effort de restauration.

GESTION DES RISQUES

En Belgique, *C. helmsii* est disponible dans le commerce horticole et son introduction accidentelle subséquente dans la nature est donc très probable. La dissémination à partir des pays voisins, bien que possible, est considérée comme une voie d'introduction mineure de l'espèce dans notre pays. Une fois établies, les petites populations peuvent parfois être contrôlées si détectées suffisamment tôt. Aux stades ultérieurs de l'envahissement les actions de contrôle pour maintenir les populations existantes à un niveau acceptable sont habituellement extrêmement difficiles à mettre en place, laborieuses et onéreuses.

Les moyens de contrôle existants incluent l'arrachage manuel ou mécanique de la plante ainsi que des mottes de terre envahies (moyens efficaces à petite échelle uniquement). Ces mesures peuvent être combinées avec une occultation prolongé au moyen de bâches (empêchant la lumière de passer) ou de mousse organique chaude ou l'inondation des populations avec des teintures aqueuses ou de l'eau salée (méthodes encore expérimentales). Les moyens de contrôle chimiques incluent l'utilisation de substances telles que le diquat ou des herbicides à base de glyphosate. En Belgique, l'utilisation de substances chimiques pour le désherbage en environnement aquatique est toutefois fortement limitée. Des études sur des agents de contrôle biologique sont également en cours. Dans le cadre des mesures de lutte contre cette espèce, il faut veiller à ne disséminer aucun fragment de la plante. Cela implique de nettoyer minutieusement les machines et matériel après utilisation et d'élaborer des itinéraires de transport mûrement réfléchis.

La suppression totale, par voie légale, du commerce de *C. helmsii* et de son utilisation est souhaitable. Entretemps, la promotion d'un code de conduite (tel que proposé par AlterIAS) pour les instances commerciales et une sensibilisation du grand public aux risques environnementaux liés à l'introduction de *C. helmsii* pourraient s'avérer bénéfiques.

Samenvatting

WAARSCHIJNLIJKHEID VAN VESTIGING EN VERSPREIDING (BLOOTSTELLING)

- Introductie in België

Deze soort werd in België voor het eerst in 1982 waargenomen en is nu op meer dan 80 locaties gevestigd. De handel in de soort voor sierdoeleinden en als "kunstlong" in aquaria en vijvers en het aansluitend dumpen van gekweekte planten in het wild en natuurlijke verspreiding vanuit bestaande populaties in buurlanden vormen de twee voornaamste introductiewegen van *C. helmsii*.

- Vestigingsvermogen

De klimaatomstandigheden en habitatkenmerken van de meeste Belgische waterlopen, vijvers en watergebieden beantwoorden perfect aan de ecologische vereisten van *C. helmsii*. De soort is gevestigd in duinvalleien, moerassen, vennen, moerasgronden en kommen, maar ook in meer permanente waterpartijen zoals vijvers en grachten, alsook op de oevers daarvan. Tot dusver is de verspreiding in of langs stromend water beperkt. De soort komt het vaakst voor op minerale bodem en in zoete tot licht brakke omstandigheden. Aangezien watercrassula overwegend tweeslachtig is, zijn de meeste waterrijke gebieden, stromen en vijvers (waaronder ook natuurgebieden en Natura2000 gebieden) kwetsbaar voor een invasie door de soort.

- Verspreidingsvermogen

De voornaamste verbreiding in het wild gebeurt door vegetatieve propagulen, door waterlopen, epizoöchorie en antropochorie. Kleine stengelfragmenten kunnen gemakkelijk tot nieuwe planten uitgroeien. Menselijke activiteiten kunnen de verspreiding van de soort sterk in de hand werken, met name door het wegwerpen van tuinafval en onopzettelijk transport via kledij of schoeisel, werktuigen, boten of visgerei. In natuurgebieden kunnen ook grote herbivoren een belangrijke vector vormen.

EFFECTEN VAN DE VESTIGING

- Milieu-impact

C. helmsii vormt ondoordringbare matten op het wateroppervlak en in periodiek ondergestroomde gebieden. De soort kan in water tot 3 m diep ook als volledig ondergedoken waterplant groeien. Ze kan inheemse plantensoorten verdringen en mogelijk ook de natuurlijke benthische levensgemeenschappen aantasten, vb. door het beperken van de waterdoorstroming en een verandering van het zuurstofregime. De soort duikt typisch op in pionierhabitats, zoals in gebieden waar bij natuurontwikkeling (afgraven, plaggen) de bodem werd verstoord. De aanwezigheid van watercrassula belemmert de kolonisatie van doelsoorten en hypothekeert daarmee investeringen in natuurherstel.

RISICOBEHEER

In België is *C. helmsii* beschikbaar in de tuinbouwsector. Als gevolg daarvan is de kans op onopzettelijke introductie ervan in het wild bijzonder groot. Hoewel de verspreiding van populaties via buurlanden mogelijk is, wordt deze introductieweg in ons land niettemin beschouwd als minder belangrijk. Na vestiging kunnen kleine populaties (indien voldoende vroeg gedetecteerd) soms worden bestreden. In latere stadia van invasie zijn controleacties om de populatie op een aanvaardbaar niveau te handhaven doorgaans bijzonder moeilijk, omslachtig en duur.

De bestrijding van watercrassula omvat het manueel of mechanisch verwijderen van geïnfecteerde zones door plaggen, eventueel te combineren met het langdurig afdekken met materiaal dat licht tegenhoudt, het onder zout water zetten en het gebruik van chemische bestrijdingsmiddelen zoals op diquat of glyfosfaat gebaseerde onkruidbestrijdingsmiddelen. De mogelijkheden voor het gebruik van chemische middelen voor onkruidbestrijding in een aquatisch milieu zijn in België echter heel regelt. Momenteel wordt onderzoek verricht naar het gebruik van warm organisch schuim en waterverfstoffen als beheersmaatregel. Ook wordt onderzoek gevoerd naar biologische controleagentia. Bij beheer van infectiehaarden dient erover gewaakt dat er geen fragmenten verspreid worden. Dit impliceert dat de werktuigen grondig moeten gereinigd worden en dat de transportroutes zorgvuldig worden uitgedacht.

Een totaalverbod op de handel en het gebruik van de *C. helmsii* via wetgeving is wenselijk. Intussen zou het bevorderen van een "gedragscode" (zoals voorgesteld door AlterIAS) voor de commerciële sector en de algemene bewustmaking van het publiek voor de milieurisico's die de introductie van *C. helmsii* in de natuur kan veroorzaken al een gunstige impact kunnen hebben.

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 the Belgium).

1.1 ORGANISM IDENTITY

Scientific name:	*Crassula helmsii*
Synonyms:	*Tillaea recurva, Crassula recurva*
Common names:	Australian swamp stonecrop (En.) [also called New Zealand pigmyweed but as , Crassule des étangs (Fr.), Watercrassula (Nl.)
Taxonomic position:	Domain: Eukaryota / Kingdom: Plantae / Phylum: Spermatophyta / Subphylum: Angiospermae / Class: Dicotyledonae / Order: Rosales / Family: Crassulaceae / Genus: Crassula / Species: *Crassula helmsii*.

***Remark**: the following descriptive chapters are largely inspired from the "Invasive Species Compendium" (available at http://www.cabi.org)* and the EPPO PRA on *Crasula helmsii* (EPPO 2007).

1.2 SHORT DESCRIPTION

C. helmsii is an aquatic or semi-terrestrial herbaceous succulent perennial plant with 1 mm thick round stems that are 10-130 cm long and creeping or floating (OEPP/EPPO, 2004). *C. helmsii* can grow in several different growth forms, establishing as a submersed plant in waters up to 3 m deep, and also as an emergent or semi-terrestrial plant on damp ground (Sheppard et al., 2006). The submersed form grows from a basal rosette with well-anchored roots, and can reach 1.3 m in height. The emergent form consists of short, densely packed stems in waters less than 0.6 m deep. The terrestrial form has creeping or erect stems with yellowish-green aerial leaves.

The leaves are succulent linear to narrowly oval, opposite and sessile, 4-24 mm long and 0.7-1.6 mm wide. Flowers have four petals, are white or occasionally pink, 3-3.5 mm in diameter, and are borne singly on stalks in the axils of the leaves. The fruits contain 2-5 smooth, elliptical seeds 0.5 mm long (OEPP/EPPO, 2007).

The submerged form of *C. helmsii* is adapted to assimilate carbon dioxide during night time and metabolize it during day time due to the plant's ability to employ crassulacean acid metabolism (CAM) (Keeley, 1998; Klavsen & Maberly, 2009).

1.3 ORGANISM DISTRIBUTION

Native range

C. helmsii is native to New Zealand and Australia, including the territories of New South Wales, South Australia, Tasmania, Victoria, and Western Australia (OEPP/EPPO, 2007). *C. helmsii* is known to occasionally be a nuisance in its native range (Sheppard et al., 2006). In New Zealand, it is reported as being naturally uncommon, and is known only from the west coast of the South Island from Karamea south to Haast (NZPCN, 2005). Randall (1999) also reports *C. helmsii* as being native to Papua New Guinea.

Introduced range

C. helmsii is currently naturalized in several areas of Europe, including the United Kingdom, Germany, Belgium, Ireland, the Netherlands, Denmark, France, Italy, Austria, and the Baikal region of Russia (OEPP/EPPO, 2004; 2007; NOBANIS, 2005; Afferni and Tavormina, 2007; Minchin, 2008). Presence in Spain has been reported (although not as an invasive) and in Portugal (OEPP/EPPO, 2004); however, this has since been invalidated (OEPP/EPPO, 2007). European distribution of the species is presented in figure 1. There are reports of *C. helmsii* occurring south-eastern United States of America, but the extent of distribution and current status of these populations are unknown (cabi.org).

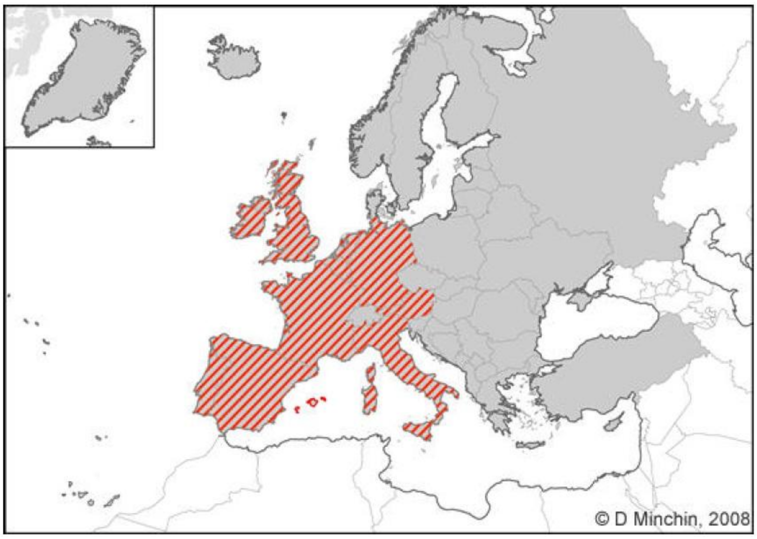

Figure 1: European distribution of *Crassula helmsii.*
Source: DAISIE (http://www.europe-aliens.org)

- **Belgium**:

C. helmsii is currently well established in Belgium. The highest densities can be found in the Maritime, Flandrian, Kempen and Brabant districts. Isolated populations are spreading in the Meuse district.

- **Rest of Europe:**

The species is now present and established in the United Kingdom, Ireland, Denmark, Germany, The Netherlands and Italy. It is very local in France and Spain where it is not yet considered invasive; however it appears to be spreading (Lansdown, 2012). Hussner (2012) also indicates presence of *C. helmsii* on the Channel Islands, Slovakia, Switzerland and the European part of Turkey.

- **Other continents:**

C. helmsii is present in the Baikal region of Russia and in the south-eastern United States in Florida and North Carolina (OEPP/EPPO, 2004; 2006; Minchin, 2008).

1.4 REASONS FOR PERFORMING RISK ANALYSIS

Naturalized in many of the EPPO region including Belgium, *C. helmsii* is considered in our country as a highly invasive species and classified in the A1 "black list" of the EPPO List of Invasive Alien Plants. In many other countries it is even classified in the A2 "black list" (Brunel, 2009). With a high vegetative cloning potential, the dense stands and mats of vegetation that are characteristic of this species when introduced outside of its native range can decrease the oxygen levels by limiting water circulation and increasing decomposition of organic material. Dense mats of *C. helmsii* also have the ability to change water hydrology and quality, negatively affecting the ecosystem in which it occurs. These mats can also cause decline in waterfront property values and aesthetic as well as adverse economic impacts in shallow water, obstructing water-borne transport, navigation and recreation activities. The plant is able to grow throughout the entire year without a dormant period, allowing it to occupy its niche year-round (CAPM-CEH, 2004). The very rapid growth of *C. helmsii* also allows it to uptake almost all the available nutrients (Environment Agency, 2003) which in case of amphibious growth gives it the capacity to outcompete and displace native plant species.

STAGE 2 : RISK ASSESSMENT

.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.

Crassula helmsii was first recorded in Belgium in 1982 in Flemish Brabant (Meerdaal Forest, Margot, 1983; Verloove, 2006; Flora Databank, 2010). Between 1982 and November 2009, according to the Floristical Institute of Belgium and Luxembourg (IFBL), 26 quadrats of 1 km² were recorded with presence of *C. helmsii* (Flora Databank, 2010); each quadrat containing one or several ponds invaded by the plant. Between 2009 and 2010, 8 new quadrats were recorded by IFBL. In Wallonia, Natagora databank (2010) showed only two sites where *C. helmsii* was present (in 3 ponds). Distance between these sites was less than 7 km. At that time the strategy in Wallonia was to simply eradicate existing populations. Despite these actions, numerous botanists throughout the Region report several recent observations in the wild (see figure 2). These new records suggest a rapid increase in population size and highlight the fact that the floristic database may underestimate the growth rate of the population. In 2010, 17 ponds were added to the database (12 IFBL quadrats; Delbart *et al.* 2011). The GBIF database (http://waarnemingen.be) indicates 13 more records in Flanders (from the Belgian coast to the western edge of the Kempen district; see figure 2). The current population establishment by district in Belgium is illustrated in figure 3.

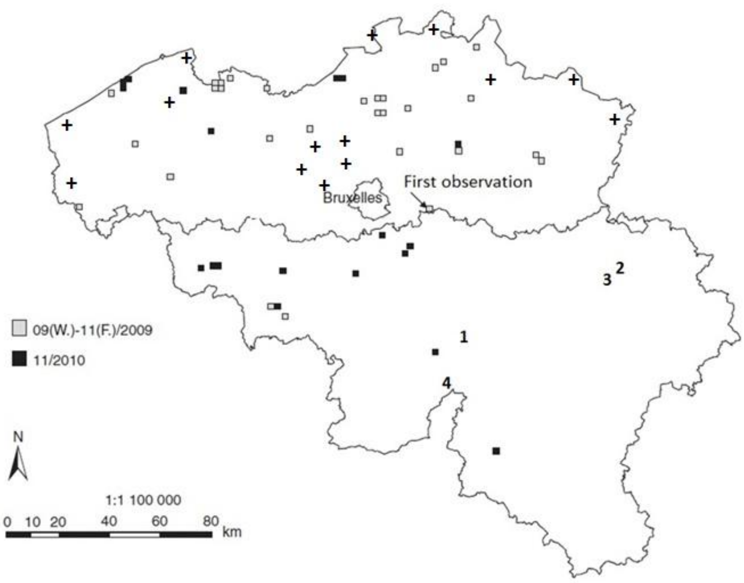

Figure 2. Geographic records of *Crassula helmsii* in Belgium. ☐: data prior to 2009; ■: data collected between 2009 and November 2010; digits represent latest records from DEMNA

database, kindly provided by S. Delaitte - DGO3 (1: Annevoie-Rouillon; 2: Olne; 3: Louveigne; 4: Agimont); W : Wallonia ; F : Flanders; **+** : extra data from waarnemingen.be.
Sources: Delbart *et al*., 2011 (SPW_DGO3_DEMNA_DNE_OFFH_BDAtlasFloredeWallonie; Instituut voor Natuuren bosonderzoek; AEF; PNPE et botanistes – Map slightly modified from the original publication of Delbart *et al.,* 2011).

Figure 3. Established population of *Crassula helmsii* by district in Belgium.
Source: http://ias.biodiversity.be

2.1.2 Present status in neighbouring countries

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

- **The Netherlands:**

In The Netherlands, *C. helmsii* was first found in 1995 and 1996 in a nature reserve near Breda. Since then, other populations have been recorded in provinces of Noord-Brabant and Zeeland. Anthropogenic and natural spread continued from year 2000 up to now and local populations can be found in most parts of the territory (see figure 4).

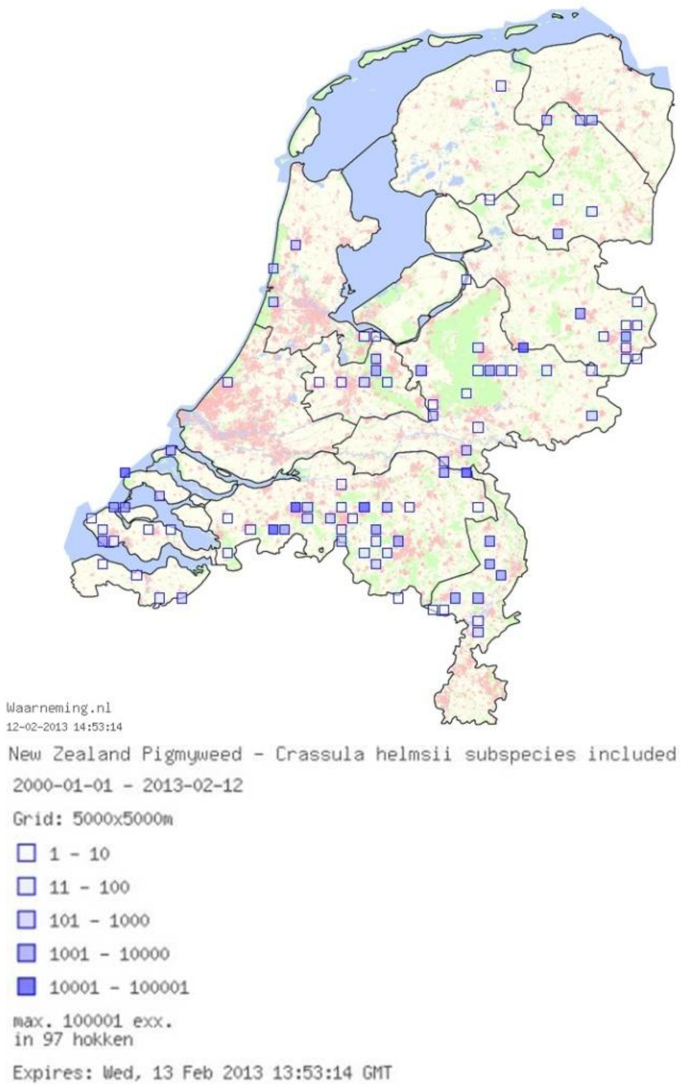

Figure 4. Geographic records of *Crassula helmsii* in The Netherlands (from year 2000 to 2013).
Source: http://waarneming.nl

- **France:**

In Britain, presence of *C. helmsii* has been recorded in several ponds. In Ille et Vilaine, the species is present along the Vilaine in ponds of Langon (close to Redon). Since 2006 observations are made at Paimpont and Amanlis. According to the Institute of geo-architecture (2007), most of Britain is potentially suitable for *Crassula helmsii*, with a risk of further dissemination and invasion. In Finistère, *C. helmsii* is present in ponds of Stang-Alar (in Brest) and pond of Costour (in Guipavas) where it dominates over native species. The species is also present in Nord-pas-de-Calais, Lorraine, Saine-et-Marne and Loire (see figure 5).

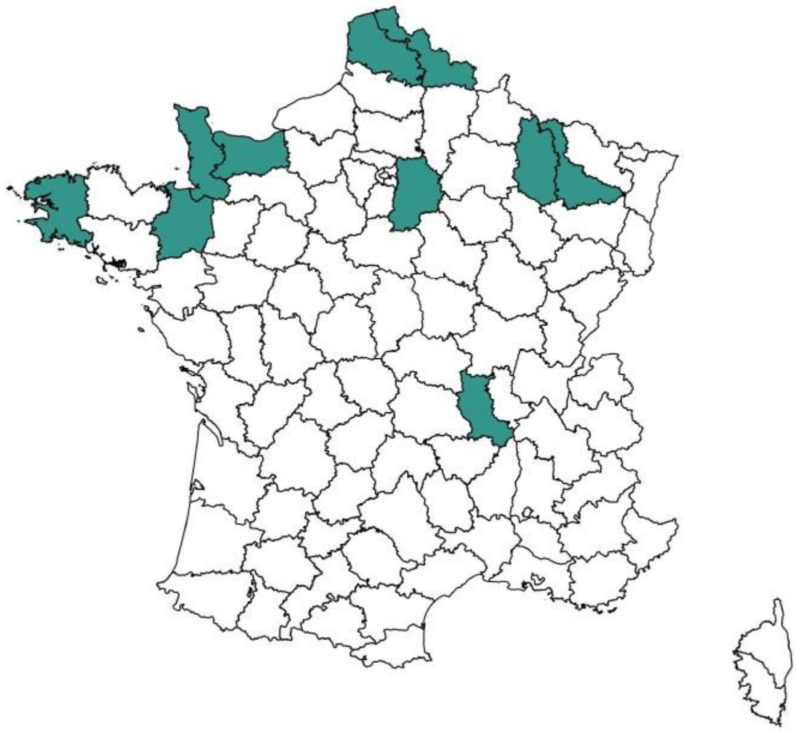

Figure 5. Geographic distribution of *Crassula helmsii* in France.
Source: « Réseau des Conservatoires botaniques nationaux » (Dec. 2009).

- **Germany**

In Germany the first observation was reported in the early 1980s. The species is now found in several aquatic systems in Hessen, Mecklenburg-Vorpommern, Niedersachsen, Nordrhein-Westfalen, Rheinland-Pfalz and Schleswig-Holstein. However, this species has not been recognized as a major threat in Germany (Hussner *et al.* 2010). This can be explained by the autecology of this species with a preference for more oceanic climate regions (Hussner 2008, 2009).

- **United Kingdom and Ireland:**

First recorded in Greensted (Essex) in 1956, the species is now widespread and abundant throughout most of England, particularly in the south, as well as in Cumbria and scattered localities in Wales, the Isle of Man, Scotland and eastern Ireland (see figure 6). According to Dadds & Bell (2008) the number of invaded sites more-or-less doubles every two years, bringing today's number to over 1000 known sites.

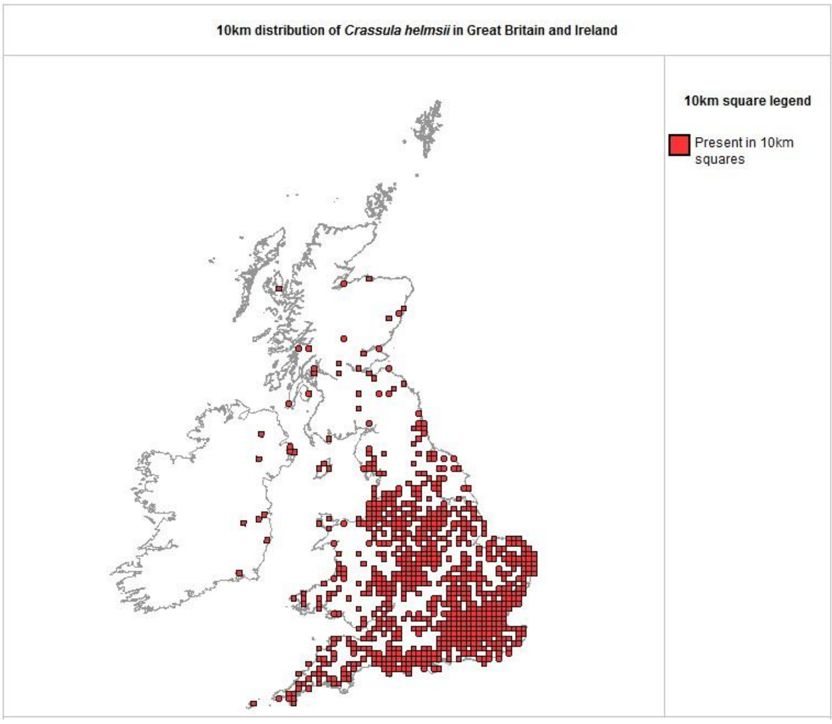

Figure 6. Geographic distribution of *Crassula helmsii* in the United Kingdom and Ireland. Source: http://data.nbn.org.uk/ 12/2012

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).

Two main pathways of entry in our country are identified:

- **1. Entry by trade in horticulture**

Crassula helmsii is used in ornamental fish ponds, aquaria or lakes as an "oxygenator" plant and is commonly sold in horticulture by garden centers and other retailers and planted by consumers (Berwick, 2009, Kelly & Maguire, 2009; Dawson & Warman, 1987). As a result *C. helmsii* has been introduced to many countries and subsequent invasion may possibly be enhanced by water currents in case of accidental propagule dissemination (by transport on clothing/footwear, translocation of machinery/equipment, live-stock animals, boats or transportation of soil or plant material).

- **2. Natural spread from neighbouring countries**

C. helmsii being present in the Netherlands (including Zeeland) and France (in Nord-pas-de-Calais among other departments), natural spread by water currents or dissemination by epizoochory is considered as a secondary pathway of entry in Belgium (Minchin, 2008; Wicks, 2004).

ENTRY IN BELGIUM
The two main pathways of entry of *C. helmsii* are the trade in horticulture (for ornamental and its "oxygenator" characteristic in aquaria's and ponds) with subsequent dissemination in the wild, and the natural spread from neighbouring countries (by propagule dissemination along water current or by epizoochory).

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

Once germinated *Crassula helmsii* appears as a small, light green tussock which grow and spread rapidly to form dense mats of vegetation. It grows throughout most of the year with minimal winter die back (Kelly & Maguire, 2009; Minchin, 2008).

The available evidence suggests that reproduction and propagation of Australian swamp stonecrop in Belgium and elsewhere in Europe are mostly vegetative, through fragmentation. Propagation by seed dispersal and germination exists in native range and under experimental conditions it has been recently shown that seeds may be able to germinate under temperate climate such as in Belgium (Denys et al., in prep; see chapter 2.5.1.A).

B/ Climatic requirements[2]

In its native hemisphere*, C. helmsii* is adapted to a wide range of climatic conditions and grows in areas where levels of precipitation range from 100 to 550 mm in summer (November–April) and 200–3000 mm in winter (May–October). In the summer the species is adapted to a temperature range of 20°C to 25°C and winter rigors are tolerated to an extreme of -6°C (including extended periods under snow; Huckle, 2005). *C. helmsii* can also tolerate drying for extended periods. Leach & Dawson (1999) indicate that in the United Kingdom, the plant has been found at a range of altitudes from sea level to 278 m. With a similar climate, Belgium falls well within the temperature and humidity range of *C. helmsii*, providing the plant with optimal growing conditions.

C/ Habitat preferences[3]

C. helmsii inhabits lakes, ponds, gravel pits, inland and coastal wetlands, marshes, swamps, rivers, canals, and irrigation ditches. It can grow in different forms, establishing submersed in waters up to 3 m deep, and also as an emergent or semi-terrestrial plant on damp ground (Sheppard et al., 2006). The morphology of the plant changes between these different growth forms according to the prevailing environmental conditions (OEPP/EPPO, 2007), although the submersed form of the plant is not known in its native range (Dawson & Warman, 1987).

The distribution of *C. helmsii* in Australia and Europe shows that the species is suited to a wide variety of freshwater habitats. Resistant to shade for extended periods, *C. helmsii* has been found in ponds and lakes with natural water chemistry ranging from acid to alkaline, and the plant has also been recorded in semisaline sites (Centre for Ecology and Hydrology Dorset, 2002; Denys & Packet 2004). In its native area, *C. helmsii* inhabits water bodies over a wide range of climates.

This aquatic plant colonizes inland wetlands (marshes, peat bogs), coastal wetlands, incl. dune slacks, continental waters (water courses, ponds, lakes, etc.) and their banks , dry river beds). Within its native range, *C. helmsii* inhabits marginal situations in many riverine habitats; however, within the United Kingdom the plant has not effectively made the transition from static or slow-flowing systems to more demanding habitats such as river margins. This also appears to be the case in Belgium. Studies have shown that the biomass production of *C. helmsii* in artificial stream systems can be greater than that of other species, including the invasive plant *Elodea canadensis* (Dawson & Warman, 1987), highlighting the potential of this plant to colonize river systems (Leach & Dawson, 1999).

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.

3

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

D/ Food habits[4]

Not applicable.

E/ Control agents

No natural control agents have been detected within introduced range of the species.

F/ Establishment capacity in Belgium

Establishment capacity in Belgium is considered high in all districts of the territory. Anthropogenic introduction (voluntary or not) and subsequent dissemination by natural means (water current displacing propagule or transport by epizoochory) may occur with a high probability and most aquatic and semi-terrestrial ecosystems in our territory provide suitable ecological conditions for effective population growth.

G/ Endangered areas in Belgium

All humid areas in Belgium (including natural reserves and Natura2000 sites) are potentially suitable habitat for *C. helmsii* introduction and proliferation (see figure 7).

Figure 7. Threat from *Crassula helmsii* on Belgian endangered areas.
Source: AlterIAS (http://www.alterias.be)

4 For animal species only.

Establishment capacity in the Belgian geographic districts:

Districts in Belgium	Nowadays environmental conditions for species establishment[5]	Environmental conditions for species establishment under increasing temperature due to climate change
Maritime	Optimal	Optimal
Flandrian	Optimal	Optimal
Brabant	Optimal	Optimal
Kempen	Optimal	Optimal
Meuse	Optimal	Optimal
Ardenne	Optimal	Optimal
Lorraine	Optimal	Optimal

ESTABLISHMENT CAPACITY AND ENDANGERED AREAS IN BELGIUM

Climatic conditions and habitat characteristics of most Belgian water courses and ponds fit within the ecological requirements of *C. helmsii*. Belgium is therefore a place where the species shows effective and potentially high establishment capacity. *Crassula* being essentially aquatic and/or closely associated to surface water, most wetlands, streams and ponds (including sensitive areas, natural reserves and Natura2000 sites) are considered highly vulnerable to *C. helmsii* invasion.

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

2.1.5 Dispersion capacity

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

A/ Natural spread

Local dispersal is mainly ensured by vegetative reproduction and propagules can remain viable for more than a year. Plant parts (even single nodes on stem fragments of 10 mm in length) can root to generate new plants and are transported by flowing water and mud. It can also be spread by attaching to animals (e.g. cattle). The possibility that the species can be dispersed by wading birds remains undocumented (EPPO 2007).

In its native range *C. helmsii* flowers abundantly and produces viable seeds. Elsewhere, seeds (formerly believed to be unviable) may be able to germinate as suggested by recent successful germination experiments carried out within the RINSE project (http://www.rinse-europe.eu) in Belgium (Denys et al., in prep). In addition, turions (short shoots with very short internodes, which break off easily) are produced in the autumn and as these float, they are an effective mean of colonization within wetland systems.

B/ Human assistance

The key pathway is its intentional introduction as an ornamental plant for aquaria and garden ponds. Plants are transferred by human activities from these actively managed habitats to unintended ones. In addition, *C. helmsii* is often found as a 'contaminant' with other traded water plants (Environment Agency, 2003).

The plant can also be accidentally dispersed by human activities, by escaping from garden centers, by transfer from pond to pond, by anglers and their equipment (on fishing kit, waders, etc.), by boats, machinery used to manage water bodies, by children pond dipping (Leach & Dawson, 1999) or even carried on people's boots (Watson, 2001).

DISPERSAL CAPACITY
Main dispersion in the wild is ensured by propagules produced vegetatively and disseminated by water currents or epizoochory. Human activities greatly enhance dispersal capacity by lack of precautions during displacement of horticultural residues or accidental transport on human clothes and footware, machinery, boats or fishing equipment.

2.2 EFFECTS OF ESTABLISHMENT

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

2.2.1 Environmental impacts

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

A/ Competition

C. helmsii is winter hardy and has the ability to form 100% surface cover, giving it the capacity to outcompete and displace native plant species which typically die back in the winter (OEPP/EPPO, 2007; Habitas, 2009). A thin covering of *C. helmsii* can cause significant germination suppression in some plant species (Langdon *et al*., 2004). Dense mats suppress native flora and drastically deplete natural benthic communities by creating poor ecosystem quality for invertebrates, amphibians, and fishes (CAPM-CEH, 2004; Minchin, 2008; Branquart *et al*., 2008). Decomposing mats of *C. helmsii* also have the ability to cause fish kills by creating severe fluctuations in dissolved oxygen levels in the water (OEPP/EPPO, 2007).

Several rare or threatened native species may be negatively impacted by the spread of *C. helmsii* (OEPP/EPPO, 2007). Ultimately, invaded zones may become monospecific formations reducing drastically native biodiversity. Reduced breeding success of the Great Crested Newt (*Triturus cristatus*), an Appendix 2 Habitat Directive Species, may be attributed to invasion of ponds by *C. helmsii* that reduces native plant germination. Some of these plant species may be of importance to newt breeding (Langdon et al., 2004) and if missing, become a possible contributing factor for Great Crested Newt reduced breeding success (Watson, 1999). In the united Kingdom, the rare starfruit plant, *Damasonium alisma,* is thought to be threatened by *C. helmsii* (Watson, 2001). *C. helmsii* may smother *Callitriche* spp., and outcompete charophytes (stoneworts) for space (Habitas, 2009). In addition, a study carried out in England shows a significant reduction in the diatom *Synedra delicatissima* caused by the introduction of *C. helmsii* (Habitas, 2009).

B/ Predation/herbivory

No species are known to preferentially graze *C. helmsii*, but some fish species, e.g. grass carp (*Ctenopharyngodon idella*) will eat it if other resources are rare.

C/ Genetic effects and hybridization

No genetic effects or hybridization reported.

D/ Pathogen pollution

No pathogen pollution reported.

E/ Effects on ecosystem functions

Dense stands and mats of *C. helmsii* can decrease the oxygen levels by limiting water circulation and increasing decomposition of organic material. These mats also have the ability to change water hydrology and quality, affecting negatively the ecosystem in which it occurs (Branquart *et al*., 2008).

ENVIRONMENTAL IMPACTS
***C. helmsii* forms dense mats over the surface (up to 3 meter deep) outcompeting other native plant species and possibly depleting natural benthic communities (amphibians, fishes, invertebrates and diatoms) by limiting water circulation and creating severe fluctuations in dissolved oxygen level.**

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).

C. helmsii has been found to limit water flow in irrigation channels and flood-control systems (Kelly and Maguire, 2009; Branquart *et al*., 2008). In addition, the loss of recreational and aesthetic value associated with *C. helmsii* can also cause a decline in waterfront property values, as well as possible declines in tourism related revenue for communities. In 1999, Leach and Dowson put an estimate on the control cost of *C. helmsii* between 1.45 and 3 million euro to manage 500 sites over 2-3 years (Leach and Dawson, 1999). In the UK, the cost of control of this species is estimated at 2.5 to 3.5 million euro (Dadds & Bell, 2008; AlterIAS). Kelly and Maguire (2009) estimate the cost of eradication to a maximum of 600 euro for a small scale program (i.e. garden pond). This price can reach 6000 euro for larger area such as a ponds or a small river systems and will require additional funding on a continuous basis until eradication is achieved. Should a lake, canal, or river system become colonized, costs associated will increase and are estimated to fall between 60,000 and 115,000 euro for the first year of action.

C. helmsii is sold in garden centers and nurseries as a submerged oxygenating plant for aquariums and water garden ponds (OEPP/EPPO, 2007). Its overall economic value is considered as minor minor by the Invasive Species Compendium (http://www.cabi.org), and alternative non-invasive aquarium and pond species are readily available (AlterIAS).

Australian swamp stonecrop may also have adverse economic impacts where it forms dense mats in shallow water, obstructing water-borne transport and navigation and negatively impacts aquaculture and fisheries.

B/ Social impacts

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

C. helmsii can form dense mats that impede recreational activities such as boating, fishing, swimming, water skiing, canoeing, and kayaking. In addition, unsightly mats of vegetation decrease aesthetic values of water bodies, and can be mistaken as dry land which can present significant danger to animals (there are occasional reports of death of pets which mistake carpets of Australian swamp stonecrop for land) and humans (Sheppard et al., 2006).

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.

From the two main pathways of *C. helmsii* entry in Belgium identified in chapter 2.1.3. (entry by trade in horticulture and natural spread from neighbouring countries), entry by trade in horticulture can be pointed out as having the highest potential of causing unwanted dissemination and invasion in our country. *C. helmsii* being readily found in garden centres or with retailers for aquaria and ponds ornament and oxygenation, chances of subsequent dissemination by natural means (transport by current) or human/animal assistance (transport of plant fragments on clothing, machines, discarding of waist from aquaria without precautions or by epizoochory) are greatly enhanced through this trade.

Natural spread from neighbouring countries is considered as a secondary pathway of entry. In France, the species is only present in small and localized populations (not yet considered as invasive) and in The Netherlands, although the species is present, transfer by machinery, cattle or other vectors across the border is considered relatively unlikely. Moreover, most streams crossing The Netherlands-Belgian border flow northward thus reducing the chance of natural spread from The Netherlands to Belgium.

3.2 PREVENTIVE ACTIONS

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

As pointed out by EPPO (2007), *C. helmsii* is still sold even though no essential interest is served by continuing the trade. Its overall value is minor, and alternatively, other suitable noninvasive aquarium and pond plant species are available. Continuation of trade, introduction and movement will have negative and almost irreversible economic and environmental impacts. The Ornamental Aquatic Trade Organization (OATO, 2003) recommends to its members that the plant should no longer be sold.

In Florida, *C. helmsii* is considered as a noxious weed and listed as a prohibited aquatic plant “Class 1” (USDA-NRCS, undated). In North Carolina it also considered as a noxious aquatic weed for which importation, sale, use, culture, collection, transportation, and distribution are regulated (USDA, 2006). In the state of Minnesota the plant is also prohibited (Minnesota Department of Natural Resources, 2006) although it does not occur in neither of these two states (NC & MN).

In the EPPO region, the species is reported to be invasive in the United Kingdom or potentially invasive in the Netherlands and Germany. In 2006, *C. helmsii* was recommended for regulation in the EPPO region as an A2 pest. Suggested measures in EPPO Standard PM 3/67 (OEPP/EPPO, 2006) put a particular emphasis on the obligation to report findings, on publicity, on surveillance, as well as on the needs for the establishment of an eradication action plan.

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

- **Action 1: Amend existing legislation**

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

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

A priority action to prevent the spread and release of invasive species such as *C. helmsii* is to promote wide use and implementation of the Invasive Species Codes of Practice (ISCP, see table 1) and to support these with literature and information leaflets for both the horticultural sector and the general public. *C. helmsii* is valued as an ornamental plant, therefore educational programs must be directed to educate the public about the dangers this plant poses outside its native range. Teaching water managers how to clean equipment in a way that decreases the chance of transmission is one way to lessen the prevalence of human-mediated transport. Additionally, information should be disseminated regarding responsible propagation and cultivation of this species if it remains to be sold (which is an undesired scenario). In Belgium, a large information campaign was promoted by AlterIAS (http://www.alterias.be). Such initiatives enhance awareness of the risks caused by invasive species such as *C. helmsii,* facilitate early warning and correct identification and provide valuable measures for careful culture and manipulation, as well as trade reduction, by proposing alternative garden plants through detailed Invasive Species Codes of Practice (see table 1), targeting the public at large as well as retailers. As the species is still widely available, there is an opportunity for education at various points along the horticultural trade pathway (from distributor to introduction).

ISCP for horticultural professionals	ISCP for the general public
1.Be informed about the Belgian alien species list	1.Be informed about the Belgian alien species list
2.Stop selling and/or planting invasive alien species	2.Avoid buying and planting alien species

3.Spread information about invasive alien species to customers and the general public	3.Choose non-invasive native plants as an alternative to alien species
4. Promote the use of alternative, non-invasive plants	4.Do not dump vegetal residues in nature
5. Take part in early invasive alien species detection actions	5. Share your knowledge and awareness about invasive plants and issues related to their introduction

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

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

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

(i) Prohibition of organism importation, trade and holding

Major invasive alien plants have already been identified as invasive by EPPO (see A1 and A2 Lists, the List of Invasive Alien Plants, and the Alert List). *Crassula helmsii* has been the object of a Pest Risk Analysis and is recommended for regulation to the 50 EPPO member countries. EPPO list of Invasive Alien Plants for which EPPO strongly recommends countries endangered by invasive species, such as *Crassula helmsii*, to take measures to prevent their introduction and spread, or to manage unwanted populations. Although this species has or could have in the future huge detrimental effects on agriculture, the environment and local economy, it is still traded in huge quantities for outdoors ornamental purposes. A species used outdoors is assumed to survive climatic conditions occurring in the EPPO region. Using a species outdoors increases its establishment probability as well as its transfer to unintended habitats (the probability of a species escaping from a garden is higher than from an aquarium). This characteristic therefore appears important in determining the success of invasion of a traded aquatic species. This species is still present on the market in significant amounts, a factor which is recognized to increase introduction and the probability of establishment and spread (Mulvaney, 2003).

Several countries have banned the importation or sale of exotic plants, such as *C. helmsii*, in attempts to minimize the chance of introduction to non-native regions. In the UK, *C. helmsii* has been added to Schedule 9 of the Wildlife and Countryside Act 1981, making it an offence to deliberately plant or cause this species to grow in the wild. In Scotland, *Crassula helmsii* meets criterion 2 of the Scotland's Species Action Framework as an invasive non-native species which presents a great risk to biodiversity. Plantlife Scotland has produced a leaflet highlighting species that are a problem when planting out ponds, including *C. helmsii*. It is also included in the Plantlife Flora Guardian program for Scotland, using volunteers to record its spread (SNH, 2009). In Ireland an Invasive Species Action Plan has been developed for *Crassula helmsii* and includes trade restriction and public awareness campaign. Management plans include formulating a comprehensive baseline distribution followed by prioritized eradication efforts with a goal of complete eradication.

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

Since involuntary dissemination is quasi impossible to avoid, preventive measures including restriction of its sale and planting as well as increasing public awareness about its environmental and economic impacts will be determinant in the control or *C. helmsii* in non native countries.

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)?

C. helmsii reproduces mainly vegetatively with dissemination of small propagules or turions (see chapter 2.1.5 A), new population may develop at great distance, from a single fragment of the plant.

In the early stage of invasion, the population may thus be very cryptic until rapid growth transforms it into a dense mat. At this later stage only, the population becomes obvious. It is also common that numerous small satellite stands are formed and may remain unnoticed for extended period. The conditions that lead to high abundance are not well known (L. Denys, pers.comm.).

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

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

The precautionary principle should be applied as a general rule.

As *C. helmsii* is tolerant to shade over long periods, to frost and to desiccation, it cannot easily be controlled. Early and effective treatment saves efforts and preserves native species. The objective is to restore optimal conditions for native species and allow the natural seed bank to re-establish the natural community (Center for Ecology and Hydrology Dorset, 2002).

- **Mechanical control**

When establishment is recent, removal of the sod is probably the best mean of controlling new population development (J. Packet, pers.comm.). At later stage, hand pulling of *Crassula helmsii* is considered to be ineffective as regrowth is very rapid. Mechanical control should be avoided as it produces more fragments which are able to disseminate the plant downstream or re-infest the treated area. Flame-throwers do not provide sufficient heat to kill the roots (Dawson & Henville, 1991), but freezing with liquid nitrogen has been effective on small areas. Fragments should be removed from footwear and other equipment – e.g. spades, excavators' buckets – before leaving the site. On medium surfaces (20–1000 m²), the risk of spread can be greatly reduced by the use of a fence with fine wire mesh (5 mm) to enclose the area to be treated. This area should be about twice as large as the stand of *C. helmsii* to allow for the inclusion of areas in which the plant has probably already spread but is not yet visible. Any fine wire-mesh fence placed around the stand should not be removed until all regrowth has been eliminated. Dredging of marginal and emergent material throughout the year can be effective (Environment Agency, 2003).

On small areas (1–20 m²), covering with black plastic or carpet can effectively eliminate small patches, but the shading material should remain in place for at least eight weeks, and preferably for six months (Centre for Aquatic Plant Management, 2004). This process is very labour intensive and causes much disturbance (Bridge, 2005). It is recommended that all dead plant material be removed to reduce potential oxygen depletion through decomposition.

- **Chemical control**

On sites with large stands (> 1000 m²), chemical control may prove to be a practical alternative, but would need to be used with great care in the natural environment. *C. helmsii* is susceptible to herbicide formulations containing diquat and glyphosate (Dawson, 1996; CAPM-CEH, 2004). Diquat has been withdrawn from aquatic use in the EU. In place of this, it is possible to use dichlobenil applied in February or March when the plant is still completely submerged. This also to allow local native local flora to regenerate from the seed bank to regenerate the local flora after treatment. Glyphosate can be applied to any emergent material, either on the bank or in the water, as long as it is applied on dry surfaces of the plant. Only formulations of glyphosate which are specifically recommended for use in aquatic situations should be used. Glyphosate should be applied from April to the end of November, when the majority of the plant is emergent (Centre for Aquatic Plant Management, 2004). Mechanical removal of dead plant material which has been treated with herbicides is recommended to reduce oxygen depletion by decomposing plant material (Centre for Aquatic Plant Management, 2004).

It is important to note that the use of chemicals in and nearby watercourses is illegal in Flanders. In Wallonia, the use of herbicide is only tolerated on paved roads or sidewalks, driveways or other surfaces covered by gravel and cemetery's pathways (Fédération Inter-Environnement Wallonie)

In an English nature reserve, hot biodegradable foam made of coconut and corn sugars was reported as being able to control approximately 50% of the population, but did not eradicate it (Bridge, 2005). Hydrogen peroxide has been experimented with as a potential control method, but only plant scorching and temporary suppression of biomass was achieved (Dawson and Henville, 1991).

- **Biological control**

There are no known control agents for this plant. It can be eaten by grass carp when the infestation is small, but *C. helmsii* is not its preferred food (Dawson & Warman, 1987). Dense infestations cause severe fluctuations in dissolved oxygen contents of the water and most fish species will not survive (Centre for Aquatic Plant Management, 2004; Centre for Ecology and Hydrology Dorset, 2002). Moreover, introduction of grass carp (*Ctenopharyngodon idella*) can negatively impact the coexisting native submerged vegetation, and its introduction is even prohibited in some countries (EPPO 2007).

- **Integrated management**

The combination of methods (physical removal, shading, and herbicide treatment) has been found to be the most effective means for controlling *C. helmsii* populations. The spraying of plant material with herbicide followed by covering with black or UV sheeting or physical removal are both effective and may be repeated until eradication is obtained (CEH, 2004; Kelly & Maguire, 2009).

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

Physical removing, shading and herbicide treatment though effective to prevent *C. helmsii* invasion are non-specific means of control. Either one of these actions will inevitably cause serious damage to local flora or fauna by intoxication (in case of chemical control), habitat disturbance and ecosystem service alteration. These side effects will indeed drastically affect native species.

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

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

When invasion is detected at an early stage (plant cover of less than 1 m² to a maximum a few m²), eradication can be undertaken with a relatively high probability of success. If adequate eradication action is managed in accordance with all mandatory precautions and regular subsequent monitoring (to detect secondary invasion), then relatively good results in long term eradication can be expected.

After control action was carried on, treated sites should be monitored regularly at intervals of 3–6 months for at least five years following an apparent elimination of *C. helmsii*. Treated and adjacent areas must be carefully examined for developing shoots or small buried rhizomes. The choice of methods depends on the growth form and extent of the *C. helmsii* stand but also on the extent of native vegetation that remains within the site.

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

If widely spread, actions to eradicate the species or to keep it under an acceptable population limit are considered as extremely difficult, laborious and costly.

In England, a management study conducted in the Lound Lakes tested several methods of controlling *Crassula helmsii*. Although none appear to be capable of complete eradication, control with glyphosate and Waipuna hot foam, a biodegradable organic compound of coconut and corn sugar which breaks down the cellular structure of the *C. helmsii*, has been used to reduce populations which threaten pillwort (*Pilularia globulifera*). Researchers also prevent its spread by installing mesh netting around invaded bodies of water (Berwick, 2009). Glyposate, Waipuna hot foam, and burial were used in a similar management project in the Old Moor Royal Society for the Protection of Birds Reserve. Glyphosate and Waipuna hot foam caused only 50% mortality. Burial yielded 100% mortality but was very labor intensive and caused significant disturbance (Bridge, 2005). The use of Reglone (Diquat) was employed to control *C. helmsii* in at the Dungeness RSPB Reserve, Kent England and achieved 70% mortality. Follow up spraying was required to manage re-growth. Eradication was not possible but manageable control was obtained (Gomes, 2005). In The Lodge (Royal Society for the Protection of Birds, RSPB), shading using black polythene was conducted on *C. helmsii* populations for six months. The treated population was killed but recolonization by outlying, untreated plants quickly resulted (Wilton-Jones, 2005).

RISK MANAGEMENT SUMMARY

In Belgium *C. helmsii* is available in horticultural trade and subsequent accidental introduction into the wild is highly likely to occur. Spread from populations in neighbouring countries, though possible is considered as a minor pathway of entry in our country. Once established, small populations (if detected early enough) can be controlled with a relatively high chance of success. At later stages of invasion, control actions to keep the population to an acceptable level are considered as extremely difficult, laborious and costly.

Means of control include mechanical removing of infested sod (efficient at early stage only), introduction of a control agent (e.g. *Ctenopharyngodon idella* often inefficient and even prohibited in some countries) and the use of chemicals such as diquat or glyphosate based herbicide. The use chemical weed control in an aquatic environment is, however, 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 integrated non-chemical methods.

Preventive actions should lead to a total ban of *C. helmsii* trade, utilization and possession through amendments of existing legislation. Promoting, highlighting and supporting an "Invasive Species Code of Practice" (such as proposed by AlterIAS) to commercial sector bodies and to the great public could raise awareness on environmental risks caused by *C. helmsii* introduction (and subsequent possible invasion).

LIST OF REFERENCES

Afferni, M., Tavormina, G. (2007). Native *Crassula* in Italy. International Crassulaceae Network. http://www.crassulaceae.net/index.php?option=com_content&view=article&id=138:native-crassula-in-italy-uk&catid=43:speciescrassula&Itemid=5

AlterIAS. http://www.alterias.be/fr/que-pouvons-nous-fairen/les-codes-de-conduite-sur-les-plantes-invasives

Berwick, H. (2009). *Crassula helmsii* at Lound Lakes Management Options. Broads Authority - The broads, a member of the National Park family. Essex and Suffolk Water.

Branquart, E., Stiers, I., Triest, L., Vanderhoeven, S., Van Landuyt, W., Van Rossum, F., Verloove, F. (2008). *Crassula helmsii* - Australian swamp stonecrop. Invasive Species in Belgium. http://ias.biodiversity.be/species/show/50

Bridge, T. (2005). Controlling New Zealand pygmyweed *Crassula helmsii* using hot foam, herbicide and by burying at Old Moor RSPB Reserve, South Yorkshire, England. Conservation Evidence. 2, 33-34.

Brunel, S. (2009). Pathway analysis: aquatic plants imported in 10 EPPO countries. EPPO Bulletin. 39 (2): 201-213.

CAPM-CEH (2004). Centre for Aquatic Plant Management, Center for Ecology & Hydrology. Wallingford, UK. http://www.capm.org.uk

Centre for Ecology and Hydrology (CEH). 2004. Information Sheet 11: Australian Swamp Stonecrop

Centre for Aquatic Plant Management. (2004). *Information sheet 11: Australian swamp stonecrop*. Centre for Ecology and Hydrology, Natural Environment Research Council (GB). http://www.ceh.ac.uk/sections/wq/CAPMInformationsheets.htm

Centre for Ecology and Hydrology Dorset. (2002). *Crassula helmsii focus on control – an update*. Natural Environment Research Council (GB). http://dorset.ceh.ac.uk/River_Ecology/Botany_Research/Botany_Research_Pictures/Crassula_Helmsii.pdf

Dadds, N., Bell, S. (2008). Invasive non-native plants associated with fresh waters. A Guide to their identification. Prepared on behalf of Plantlife, Royal Botanic Garden Edinburgh, Scottish Natural Heritage, Scottish Environment Protection Agency, Scottish Water. Species action framework. http://www.snh.org.uk/pdfs/species/B236924.pdf

Dawson, F.H. (1996). *Crassula helmsii*: Attempts at elimination using herbicides. Hydrobiologia 340(1-3): 241-245.

Dawson, F.H., Henville, P. (1991). An investigation of the control of *Crassula helmsii* by herbicidal chemicals (with interim guidelines on control). Final report. Peterborough, UK: Nature Conservancy Council, 107 pp.

Dawson, F.H., Warman, E.A. (1987). *Crassula helmsii* (T. Kirk) Cockayne: is it an aggressive alien aquatic plant in Britain? Biological Conservation 42(4): 247-272.

Delbart, E., Monty, A., Mahy, G. (2011). Gestion de *Crassula helmsii* en Belgique plus difficile qu’il n’y paraît? EPPO Bulletin 41 (2) : 226-231.

Denys, L., Packet, J. (2004). *Crassula helmsii* ook in brak water. Dumortiera 82: 27-28. Nationale Plantentuin, Meise.

Denys L., Packet J., Jambon W., Scheers K. (submitted). Dispersal of the non-native invasive species *Crassula helmsii* may involve seeds and endozoochorous transport by birds.

Environment Agency. (2003). Guidance for the control of invasive weeds in or near fresh water. Bristol, UK: Environment Agency

EPPO European and mediterranean Plant Protection Organization (2007). Data sheets on quarantine pests. Fiches informatives sur les organismes de quarantaine *Crassula helmsii*. *Bulletin OEPP/EPPO* 37: 225229

Fédération Inter-Environnement Wallonie. http://www.sante-environnement.be

Flora Databank. (2010). Instituut voor Natuur- en bosonderzoek. http://flora.inbo.be

Gomes, B. (2005). Controlling New Zealand pygmyweed *Crassula helmsii* in field ditches and a gravel pit by herbicide spraying at Dungeness RSPB Reserve, Kent, England Conservation Evidence (2005) 2, 62.

Habitas. (2009). *Crassula helmsii*, New Zealand Pigmyweed. Holywood, Ireland: National Museums Northern Ireland. http://www.habitas.org.uk/invasive/species.asp?item=4639

Huckle, J. (2005). *Crassula helmsii ,* New Zealand Pygmyweed. Invasive Aliens in Northern Ireland. University of Liverpool (GB). http://www.habitas.org.uk/invasive/species.asp?item=4639

Hussner, A. (2008). Ökologische und ökophysiologische Charakteristika aquatischer Neophyten in Nordrhein-Westfalen. Dissertation, Heinrich-Heine-Universität Düsseldorf, 192 pp.

Hussner, A. (2009). Growth and photosynthesis of four invasive aquatic plant species in Europe. Weed Research, 49: 506–515.

Hussner, A., Van De Weyer, K., Gross, E.M., Hilt, S. (2010). Comments on increasing number and abundance of nonindigenous aquatic macrophyte species in Germany. Weed Research 50: 519–526.

Hussner, A. (2012). Alien aquatic plant species in European countries. Weed Research 52 (4): 297–306.

Invasive Species Compendium. http://www.cabi.org

Institut de géoarchitecture. (2007). Plantes invasives. Compte-rendu de l'étude. 55p. Brest métropole océane. Brest.

Keeley, J.E. (1998). CAM photosynthesis in submerged aquatic plants. The Botanical Review 64(2):121-175.

Kelly, J., Maguire, C.M. (2009). New Zealand Pigmyweed (*Crassula helmsii*) Invasive Species Action Plan. Prepared for NIEA and NPWS as part of Invasive Species Ireland.

Klavsen, S.K., Maberly, S.C. (2009). Crassulacean acid metabolism contributes significantly to the in situ carbon budget in a population of the invasive aquatic macrophyte *Crassula helmsii*. Freshwater Biology 54: 105–118.

Langdon, S.J., Marrs, R.H., Hosie, C.A., McAllister, H.A., Norris, K.M., Potter, J.A. (2004). *Crassula helmsii* in UK ponds: effects on plant biodiversity and implications for newt conservation. Weed Technology 18:1349-1352.

Lansdown, R.V. (2012). in https://secure.fera.defra.gov.uk/nonnativespecies/home/index.cfm

Leach, J., Dawson, H. (1999). *Crassula helmsii* in the British Isles - an unwelcome invader. British Wildlife 10: 234-239. http://uk.geocities/jjleach@btinternet.com/invasiveweeds/crassula/BRITWILD.DOC

Minchin, D. (2008). *Crassula helmsii*. Delivering Alien Invasive Species Inventories for Europe (DAISIE). http://www.europe-aliens.org/pdf/Crassula_helmsii.pdf

Minnesota Department of Natural Resources (2006). *Minnesota Invasive Species Laws*. http://www.dnr.state.mn.us/ecological_services/invasives/laws.html

Mulvaney, M. (2003). The effect of introduction pressure on the naturalization of ornamental woody plants in South-Eastern Australia. In Weed Risk Assessment (Groves RH, Panetta FD & Virtue JG), pp. 186–193. CSIRO Publishing,Melbourne.

NOBANIS (2005). http://www.nzpcn.org.nz/nz_threatenedplants/detail.asp?PlantID=254

OATO (2003). Invasive Plants. http://www.ornamentalfish.org/aquanautconservation/invasiveplants.php

OEPP/EPPO (2004). EPPO Reporting Service 2004, No. 3. Paris, France.

OEPP/EPPO (2006). *Crassula helmsii* (Kirk) Cockayne. Report of Pest Risk Analysis. http://www.eppo.org/QUARANTINE/Pest_Risk_Analysis/PRAdocs_plants/06-12801%20PRA%20report%20CSBHE.doc

Sheppard, A.W., Shaw, R.H., Sforza, R. (2006). Top 20 environmental weeds for classical biological control in Europe: a review of opportunities, regulations and other barriers to adoption. Weed Research 46(2): 93-117.

Scottish Natural Heritage (2009). Species Action Framework Species for conservation action New Zealand Pygmy Weed.
Summary available from: http://www.snh.org.uk/speciesactionframework/saf-nzpygmyweed.asp

Randall, K. (1999). Crassula. Aquarium Frontiers - Aquatic Horticulture.
http://www.csd.net/~cgadd/aqua/ah_main/oct1999.html

USDA-NRCS (2006). The PLANTS Database Version 3. Baton Rouge, USA: National Plant Data Center. http://plants.usda.gov

USDA, NRCS (undated). *Crassula helmsii* A. Berger swamp stonecrop. The PLANTS Database, National Plant Data Center, Baton Rouge, LA 70874-4490 USA

Verloove, F. (2006). Catalogue of the Neophytes in Belgium (1800-2005). Scripta Botanica Belgica 39, 89 pp.

Watson, W.R.C. (1999). Froglog. Newsletter of the Declining Amphibian Task Force. Number 3 1. 'Amphibians and *Crassula helmsii*.

Watson, W.R.C. (2001). An unwelcome invader! Worcestershire Record, issue 10. http://www.wbrc.org.uk/WorcRedc/Issue10/invader.htm

Wicks, D. (2004). War against *Crassula helmsii*. In: 13th International Conference on Aquatic Invasive Species, 20-24 September, 2004, Ennis, County Clare, Ireland.

Wilton-Jones, G. (2005). Control of New Zealand pygmyweed *Crassula helmsii* by covering with black polythene at The Lodge RSPB Reserve, Bedfordshire, England. Conservation Evidence (2005) 2, 63.

Margot, J. (1983). La végétation aquatique des Springputten en forêt de Meerdael. Evolution et présences floristiques? Les Naturalistes Belges 64 : 199-221.