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Risk analysis of the Hottentot Figs, *Carpobrotus edulis* (L.), *C. acinaciformis* (L.)

Risk analysis report of non-native organisms in Belgium

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Adopted in date of : 11 March 2013

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Contents

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

STAGE 1: INITIATION 11
1.1 ORGANISM IDENTITY 11
1.2 SHORT DESCRIPTION 11
1.3 ORGANISM DISTRIBUTION 12
1.4 REASONS FOR PERFORMING RISK ANALYSIS 14

STAGE 2 : RISK ASSESSMENT 15
2.1 PROBABILITY OF ESTABLISHMENT AND SPREAD (EXPOSURE) 15
2.1.1 Present status in Belgium 15
2.1.2 Present status in neighbouring countries 16
2.1.3 Introduction in Belgium 18
2.1.4 Establishment capacity and endangered area 19
2.1.5 Dispersion capacity 22
2.2 EFFECTS OF ESTABLISHMENT 23
2.2.1 Environmental impacts 23
2.2.2 Other impacts 26

STAGE 3 : RISK MANAGEMENT 27
3.1 RELATIVE IMPORTANCE OF PATHWAYS FOR INVASIVE SPECIES ENTRY IN BELGIUM 27
3.2 PREVENTIVE ACTIONS 27
3.3 CONTROL AND ERADICATION ACTIONS 28

LIST OF REFERENCES 33

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Rationale and scope of the Belgian risk analysis scheme

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

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

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

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

This risk analysis is an advisory document and should be used to help support Belgian decision making. It does not in itself determine government policy, nor does it have any legal status. Neither should it reflect stakeholder consensus. Although the document at hand is of public nature, it is

1

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

important to realise that this risk assessments exercise is carried out by (an) independent expert(s) who produces knowledge-based risk assignments sensu Aven (2011). It was completed using a uniform template to ensure that the full range of issues recognised in international standards was addressed.

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

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

Photo: Alvesgaspar. Source: wikimedia Commons.

Executive summary

PROBABILITY OF ESTABLISHMENT AND SPREAD (EXPOSURE)

- Entry in Belgium

Potential pathway of entry of these South African species in Belgium (and neighbouring countries) is voluntary introduction of individuals for ornamental or soil stabilisation purpose. If planted in adequate ecological/climatic conditions, subsequent endozoochorous or hydrochorous dispersion of individuals (originally planted in Belgium or neighbouring countries) can be considered as a secondary pathway of entry.

- Establishment capacity

The risk of establishment of *Carpobrotus* spp. is likely under current conditions in Belgium. As observed in other neighbouring countries with similar climate conditions, those species could readily invade suitable habitats such as dune ecosystem along the coast. Future climate conditions may even enhance the establishment capacity of these species in this area due to a reduction of frost events in the winter.

- Dispersion capacity

Human introduction for ornamental or ground stabilization purpose is the main driving force of *Carpobrotus spp*. invasion. Their seeds may also be dispersed naturally over distances exceeding 1 kilometer through endozoochory by various mammal species like rats, rabbits and deer. Their germination capacity is enhanced through gut transfer.

EFFECT OF ESTABLISHMENT

- Environmental impacts

Carpobrotus spp. makes dense and large mats that may displace natives and-dwelling plant species due to competition for light and water. They are also known to strongly alter soil chemistry (pH and nitrogen equilibrium) as well as soil organic and nutrient contents. Hybrids among *Carpobrotus* species are very vigorous and may drastically impact their environment.

RISK MANAGEMENT

Voluntarily introduced for ornamental reasons (or possibly dispersed by endozoochory or hydrochory), *Carpobrotus spp.* are widely considered as super-invaders that outcompetes native flora, and alters biotic and abiotic soil characteristics.

Once established and widely spread *Carpobrotus edulis* and *C. acinaciformis* populations form dense mats that become very difficult to control and nearly impossible to eradicate.

Means of control include manual removing by “hand-pull” (though most of the time not efficient for large populations), and the use of chemicals such as glyphosate 2,4-D or 2.4-DP based herbicide

(chemical control is generally difficult because of existing legislation regulating their use in natural environment). The use of biological pathogen (such as *Verticillium wilt*) or control agents (e.g. scale insect) are usually not recommended because of their characteristic of being (often) non specific and the probability to cause uncontrolled effect on native plants and/or crops.

Given the fact that this species is very difficult to control, it is crucial to take preventive actions for *Carpobrotus spp*.. This should lead to a total legal trade ban.

Public awareness to consumers (garden owner, green officer and landscape architect) on risks of *Carpobrotus spp*. purchasing and planting is currently the most effective measure to reduce potential impacts on ecosystem.

Campains of promotion which highlight and support an “Invasive Species Code of Conduct” (such as proposed by AlterIAS) to commercial sector bodies and to the great public could also raise awareness on environmental risks caused by *Carpobrotus spp.* introduction (subsequent possible dissemination and invasion).

Résumé

PROBABILITE D'ETABLISSEMENT ET DE DISSEMINATION (EXPOSITION)

- Introduction en Belgique

La voie potentielle d'introduction de ces espèces sud-africaines en Belgique (et dans les pays voisins) est son introduction délibérée à des fins ornementales ou de stabilisation des sols. Plantée dans des conditions écologiques/climatiques adéquates, une dispersion par endozoochorie ou hydrochorie subséquente de l'espèce (initialement plantée en Belgique ou dans des pays voisins) peut être considérée comme une voie d'introduction secondaire.

- Capacité d'établissement

Dans les conditions actuelles, le risque d'établissement de *Carpobrotus* spp. en Belgique est probable. Comme observé dans d'autres pays voisins présentant des conditions climatiques similaires, ces espèces pourraient envahir rapidement des habitats adaptés et notamment les écosystèmes dunaires le long de la côte. Des conditions climatiques plus clémentes (prédites pour l'avenir) pourraient même favoriser la capacité d'établissement de ces espèces dans ces régions en raison de la diminution de la période de gel en hiver.

- Capacité de dispersion

L'introduction anthropique à des fins ornementales ou de stabilisation des sols constitue la principale force motrice de l'envahissement par *Carpobrotus spp.*. Leurs graines peuvent aussi être consommées par plusieurs espèces de mammifères comme les rats, les lapins et les cervidés et disséminées sur des distances dépassant 1 kilomètre par endozoochorie. La capacité de germination des graines est par ailleurs augmentée après passage au travers du système digestif des espèces consommatrices.

EFFET DE L'ETABLISSEMENT

- Impacts environnementaux

Carpobrotus spp. forment de vastes tapis denses qui peuvent supplanter les espèces endémiques par la compétition pour la lumière et l'eau. On sait aussi que cette espèce altère fortement la chimie des sols (équilibre du pH et de l'azote) ainsi que la teneur en éléments organiques et nutritifs des sols. Les hybrides de *Carpobrotus* spp. sont très vigoureux et peuvent avoir un impact encore plus marqué sur leur environnement.

GESTION DES RISQUES

Introduite délibérément à des fins ornementales (ou disséminée par endozoochorie ou hydrochorie), les *Carpobrotus* spp. sont largement considérées comme des espèces fortement envahissantes qui supplantent la flore locale et modifient les caractéristiques abiotiques des sols.

Une fois largement disséminées et établies les populations de *Carpobrotus edulis* et *C. acinaciformis* forment des tapis denses qui deviennent très difficiles à contrôler et quasi impossibles à éradiquer.

Les moyens de contrôle comprennent l'arrachage manuel (mais ce moyen n'est le plus souvent pas efficace sur les populations importantes) et l'utilisation de produits chimiques comme des désherbants à base de glyphosate 2,4 D ou 2.4-DP (le contrôle chimique est généralement difficile en raison des législations en vigueur réglementant l'utilisation des substances chimiques dans l'environnement naturel). L'utilisation de pathogènes biologiques (comme *Verticillium wilt)* ou d'agents de contrôle (p.ex. des cochenilles) n'est généralement pas recommandée en raison du caractère (le plus souvent) non spécifique de leur action et de la probabilité d'un effet incontrôlé sur les plantes et/ou les cultures locales.

Etant donné que ces espèces sont très difficiles à contrôler, il est fondamental de prendre des actions préventives pour *Carpobrotus spp.*. Celles-ci devraient mener à une interdiction totale de sa commercialisation au niveau légal.

La sensibilisation des consommateurs (propriétaires de jardin, agents d'entretien des espaces verts et paysagistes) aux risques liés à l'achat et à la plantation de *Carpobrotus spp*. est actuellement le moyen le plus efficace pour réduire son impact potentiel sur l'écosystème.

Des campagnes de promotion mettant en avant et préconisant un "Code de conduite face aux espèces envahissantes" (comme proposé par AlterIAS) pour les entreprises commerciales et le grand public pourraient également générer une prise de conscience des risques environnementaux liés à l'introduction de *Carpobrotus spp.* (ainsi que les modalités de sa dissémination et de son envahissement subséquents potentiels).

Samenvatting

WAARSCHIJNLIJKHEID VAN VESTIGING EN VERSPREIDING (BLOOTSTELLING)

- Introductie in België

Potentiële introductieweg van deze Zuid-Afrikaanse kustsoort in België (en buurlanden) is door vrijwillige introductie van individuen voor sier- of bodemstabiliserende doeleinden. Indien in gepaste ecologische/klimatologische omstandigheden aangeplant, kan de daaropvolgende endozoöchore of hydrochore verspreiding van individuen (oorspronkelijk in België of in buurlanden aangeplant) worden beschouwd als een secundaire introductieweg.

- Vestigingsvermogen

Het risico dat *Carpobrotus* spp. zich onder de huidige omstandigheden in België vestigen, is waarschijnlijk. Zoals in buurlanden met gelijkaardige klimaatomstandigheden werd waargenomen, kunnen de soorten zich vlot meester maken van geschikte habitats, zoals duinecosystemen langs de kust. Door afname van het aantal vorstperiodes in de winter waardoor de toekomstige klimaatomstandigheden de kans op vestiging van deze soort in dit gebied nog zal toenemen.

- Verspreidingsvermogen

De introductie door de mens voor sier- of bodemstabiliserende doeleinden is de voornaamste drijvende kracht achter de invasie van *Carpobrotus*. Zaden van de soort kunnen zich op een natuurlijke manier, via endozoöchorie door verschillende zoogdieren (ratten, konijnen, hertachtigen) over afstanden van meer dan één kilometer verspreiden. Het kiemingsvermogen van het zaad wordt door de mest in de hand gewerkt.

EFFECTEN VAN DE VESTIGING

- Milieu-impact

Carpobrotus spp. kan zich tot ondoordringbare matten ontwikkelen die inheemse en op zand gedijende plantensoorten in de strijd om licht en water verdringen. De planten staan er om bekend de bodemeigenschappen (balans van pH en stikstof), organische stoffen en voedingsstoffen in de bodem veranderen in hun eigen voordeel. Hybride *Carpobrotus* soorten groeien bijzonder goed en kunnen hun omgeving drastisch beïnvloeden.

RISICOBEHEER

De voor sierdoeleinden (of door endozoöchorie of hydrochorie) geïntroduceerde *Carpobrotus spp.* wordt beschouwd als een super-invasieve soort die de inheemse flora kan verdringen en zowel biotische als abiotische bodemkenmerken wijzigt.

Eens gevestigd en op grote schaal verspreid vormen *Carpobrotus edulis* en de *C. acinaciformis* ondoordringbare matten die nog moeilijk te beheersen zijn en nagenoeg onmogelijk uitgeroeid kunnen worden.

Bestrijding kan via manuele verwijdering (uittrekken), wat echter meestal niet efficiënt is voor grote populaties, en het gebruik van chemische bestrijdingsmiddelen, waaronder op glyfosaat 2,4-D of 2,4-DP gebaseerde herbiciden (Chemische bestrijding is echter doorgaans moeilijk door de bestaande wetgeving die het gebruik van dergelijke middelen in een natuurlijke omgeving regelt). Het gebruik van biologische pathogene agentia (zoals de *Verticillium verwelkingsziekte*) of bestrijdingsagentia (vb. schildluis) wordt doorgaans niet aanbevolen omwille van hun (vaak) niet-specifieke karakteristieken en hun waarschijnlijke en oncontroleerbare effecten op inheemse planten en/of gewassen.

Aangezien de soort vaak moeilijk te bestrijden is, is een preventieve aanpak cruciaal voor *Carpobrotus* spp. Het moet tot een totaal verbod op het handel van *Carpobrotus* spp. leiden.

Algemene bewustmaking van consumenten (tuineigenaren, groenambtenaren, landschapsarchitecten) rond de aankoop en het aanplanten van de *Carpobrotus spp*. is momenteel de meest doeltreffende maatregel om een potentiële impact op ecosystemen te beperken.
Promotiecampagnes die een "Gedragscode Invasieve Soorten" (zoals voorgesteld door AlterIAS) voor de commerciële sector en voor het grote publiek belichten en ondersteunen, kunnen ook het bewustzijn voor de milieurisico's veroorzaakt door introductie en vestiging van *Carpobrotus spp.* (aansluitende mogelijke verspreiding en invasie) vergroten.

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 : *Carpobrotus edulis (L.), C. acinaciformis (L.)*

Synonyms: **- *Carpobrotus edulis*** = *Mesembryanthemum edule = Carpobrotus aequilaterus = Carpobrotus edulis var. chrysophthalmus = Mesembryanthemum acinaciforme flavum*

- *C. acinaciformis* = *C. edulis* var. *rubescens = Mesembryanthemum acinaciforme.*

Common names : **- *C. edulis*** = Hottentot fig, Freeway iceplant, Cape fig, Kaffir fig (Eng.); Hottentotvijg (Nl.); Griffe de sorcière (Fr.); uña de gato, higo del Cabo, higo marino (Spanish).

- *C. acinaciformis* = Sally-my-handsome (Eng.); Hottentotvijg (Nl.); Griffe de socière (Fr.)

Taxonomic position: Kingdom: Plantae / Phylum: Spermatophyta /Subphylum: Angiospermae /Class: Dicotyledonae /Order: Caryophyllales / Family: Aizoaceae/ Genus: Carpobrotus

***Remark**: Information presented in the following descriptive chapters are for some parts inspired from the "Invasive Species Compendium" Pest Risk Analysis (PRA; available athttp://www.cabi.org) and D'antonio C., 2008 (available at http://www.issg.org).*

1.2 SHORT DESCRIPTION

Carpobrotus edulis and *C. acinaciformis* are closely related species. They are very similar and, when sympatric (e.g. in the Mediterranean basin) they may hybridize and form a hybrid complex known as *C. affine acinaciformis* (flower size and colour may therefore be variable among this complex). According to Médail (1999) and Suehs et al. (2001), only *C. edulis* and *C. affine acinaciformis* together with the different hybrids, may cause ecological disturbance in invaded countries such as France. Among *C. edulis* and *C. acinaciformis*, the most widespread in Europe is *C. edulis*. Both species, and also the hybrid complex, show stems spreading or prostrate, up to 3 m long, forming large, dense mats, sometimes rooting at the nodes. Leaves succulent, triangular in section, 4-14 cm long, 8-17 mm wide, opposite, slightly connate at the base, bright green or slightly glaucous, waxy, often tinged red along edges and becoming generally reddish or orange with age; adaxial and lateral surfaces

distinctly concave; keel denticulate, sometimes only in upper portion; tips obtuse to acute. The flowers have superficial similarity to those of Compositae but the numerous 'florets' are in fact petalloid staminodes. The flowers are terminal or on side shoots, 4-9 cm diameter; peduncles 10-50 mm long. Calyx is yellow-green, 4-6-lobed up to 6 cm long. Staminodes 50-150; in *C. edulis*, yellow changing to pink; in other taxa pink or purple from the start; usually densely streaked when dry; stamens 400-600, 6-7-seriate. Styles 8-14, free; nectary glands united to form a ring round the ovary which is conical, barely compressed, convex on top up to 3 cm in diameter. Seeds 1 x 1.5 mm, dark brown when ripe, obovate, flat, finely reticulate, on a funicle, 2-3 mm (Preston and Sell, 1988; PIER, 2005).

When the two forms are treated separately, *C. acinaciformis* is distinguished from typical *C. edulis* by flowers always pink or purple rather than starting yellow and only fading to pink; calyx oblong or nearly globose, rather than club-shaped; top of the ovary flat or slightly concave rather than 'elevated'; and leaves thickest close to the apex and narrower than they are thick, rather than being equally thick throughout their length and as wide as thick in typical *C. edulis* (Adamson and Salter, 1950). Pollen morphology has been described by Mulder (2003).

Carpobrotus spp. has inducible "Crassulacean Acid Metabolism" (CAM) when subjected to drought or salt-stress.

1.3 ORGANISM DISTRIBUTION

Native range

C. edulis and *C. acinaciformis* are sub-tropical species with a similar native distribution range. Both species are native to South Africa, growing on coastal and inland slopes round the fringes of Cape Province.

Introduced range

From its native range, *C. edulis* has been introduced (for ornamental purpose and for erosion control) into many other sub-tropical and temperate countries, but particularly to Europe, USA, Australia, New Zealand, South America, North Africa, and to some Pacific and Atlantic Islands.

In Europe, *Carpobrotus* spp. were first introduced in 1680 in Belgium (where the species did not survive) then in 1690 in England. Their first appearance on the Channel Islands occurred in 1886. Subsequently, at the end of the 19th century, these plants were introduced all along the French coasts for ornamental and soil stabilisation purpose (http://www.observatoire-biodiversite-bretagne.fr). Up-to-date distribution of *C. edulis* outside South Africa's Cape area is illustrated on figure 1.

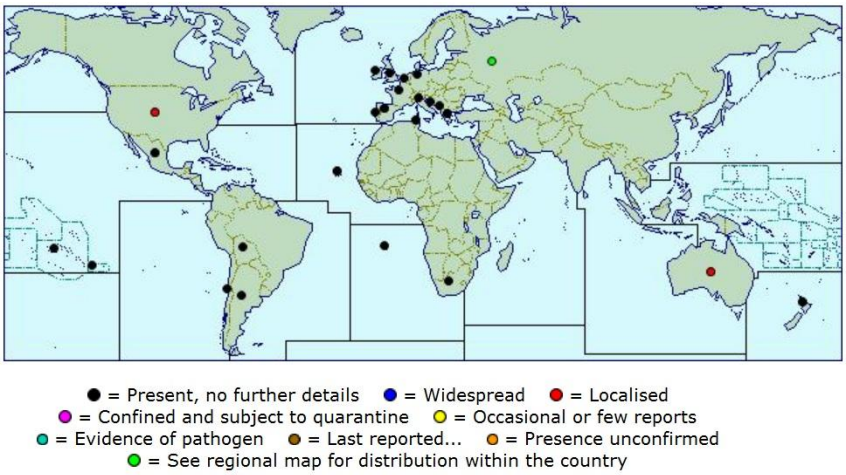

Figure 1: Geographic distribution of *C. edulis*. Source: http://www.cabi.org.

- Belgium:

Carpobrotus edulis and *C. acinaciformis* are not currently established in the wild in Belgium.

- Rest of Europe:

Northern Europe : *Carpobrotus edulis* is widely established in Great Britain and Ireland. Localized presence was reported in the Netherlands in 1991. *C. acinaciformis* is only present on Scilly Island (UK).

Southern Europe : Portugal, Madeira, Spain, Balearic Islands, Canary islands, France, Corsica, Italy, Sardinia, Sicily, Malta, Croatia, Albania, Greece, Cyprus and Gibraltar (Marco & Leblay 2010).

European distribution of *C. edulis* is presented on figure 2.

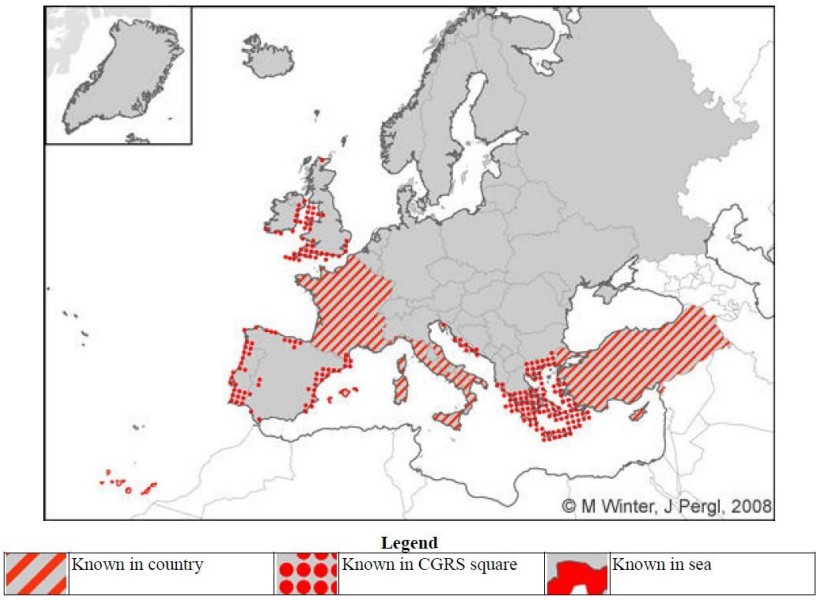

Figure 2: European distribution of *C. edulis.* Source: http://www.europe-aliens.org/

- Other continents:

East Mediterranean basin: Cyprus, Turkey, Lebanon-Syria, Israel-Jordan.

Northern Africa: Algeria, Morocco, Libya, Macaronesia (Cape Verde, Canary Islands and Madeira).
Africa - Middle Atlantic Ocean: St. Helena.

Northern America: USA (California, Florida) and Mexico.
Southern America: Chile, Argentina.
South-Central Pacific: Pitcairn Is., French Polynesia.

Australasia: Australia, New Zealand.

1.4 REASONS FOR PERFORMING RISK ANALYSIS

Carpobrotus edulis and *C. acinaciformis* are popular ornamental plans and often used for ground cover and soil-stabilization but can readily and rapidly spread forming impenetrable mats up to 20 m wide and over 50 cm deep. Both species will sometimes compete aggressively with native species (D'Antonio and Mahall 1991; D'Antonio, 1993; Roiloa *et al*. 2010; Santoro *et al.* 2012), especially low-growing native vegetation in coastal habitats. Once established, they show a high vegetative reproductive rate, and growth does not appear to be affected by herbivory or competition (D'Antonio 1993; Campelo *et al.* 1999).

C. edulis and *C. acinaciformis* form a hybrid complex when sympatric in many parts of their introduced range (Chinnock, 1972; Albert *et al.* 1997; Gallagher *et al*. 1997; Vila and D'Antonio, 1998; Suehs *et al.* 2004a). This may intensify the invasion process (Suehs *et al.* 2004a) and/or impact on the integrity of native species. *Carpobrotus spp.* can indeed decrease species diversity by preventing sand movement, which hinders the natural processes of sand blow and sand deposition sand in dune ecosystems. Both *C. edulis* and *C. acinaciformis,* and particularly their hybrid reduce soil pH, influence nutrient dynamics (Vila *et al*., 2006), and increase soil nitrogen and organic carbon contents (D'Antonio 1990a, D'Antonio and Mahall, 1991).

C. edulis and *C. acinaciformis* (including their hybrid) may be responsible for habitat micro-structure modification with subsequent loss of niches for invertebrate and small-vertebrate species (Valentine *et al*., 2007; Palmer *et al.,* 2004). The species complex also modify soil biotic properties and thus potentially affect growth of native species while enhance their own growth through positive feedbacks process (Conser *et al*., 2009, de la Peña *et al.,* 2010).

C. edulis has been observed to invade new areas following fire events in California (Zedler and Scheid 1988; D'Antonio *et al.* 1993). While not readily spread accidentally at the international level, there is continued significant risk of deliberate introduction as an ornamental plant, being readily available from nursery businesses via the internet (Invasive Species Compendium, undated).

STAGE 2 : RISK ASSESSMENT

2.1 PROBABILITY OF ESTABLISHMENT AND SPREAD (EXPOSURE)

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

2.1.1 Present status in Belgium

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

Carpobrotus edulis and *C. acinaciformis* are not established in Belgium. However the plant is still planted as an ornamental plant (particularily along the Belgian coast; see photo 1-4 and chapter 2.1.5.B).

Photo 1 - 2: Plantation of *C. edulis* as ornamental on the Belgian coast.
Photo: E. de la Peña & M. Vandegehuchte.

Photo 3 - 4: Plantation of *C. edulis* as ornamental under street name indication in Le Coq, Belgium. Photo: E. de la Peña & M. Vandegehuchte.

2.1.2 Present status in neighbouring countries

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

- **France**:

In North-Western France, *Carpobrotus edulis* is present in Department of Manche, Ille et Vilaine (Cézembre island) , Côte du Nord, Finistère (including archipel des Glénan, la pointe du Raz, Crozon peninsula, coast of Abers and the city of Brest, Morbihan and Loire (Jezequel 2006, Institut de géoarchitecture, 2007)). In Morbihan it is present on most of the littoral zones and form dense colonies. *C. acinaciformis* is only present in Morbihan. On Belle-Ile-en-Mer invasive populations are found on rocky cliffs of the island (Rivière 2007).

On the western coast of France *C. edulis* is present in Vendée, Charente-maritime, Gironde, Landes, Pyrénées Atlantiques and Loire Atlantique. *C. acinaciformis* can be found in Landes and Pyrénées Atlantiques.

Along the Mediterranean coast *C. edulis* is widespread from Pyrénées-Orientales to Var and Corsica. *C. acinaciformis* is restricted to Pyrénées-Orientales, Gard and Bouches-du-Rhône.

Geographical distribution of *C. edulis* and *C. acinaciformis* in France is illustrated on figure 3.

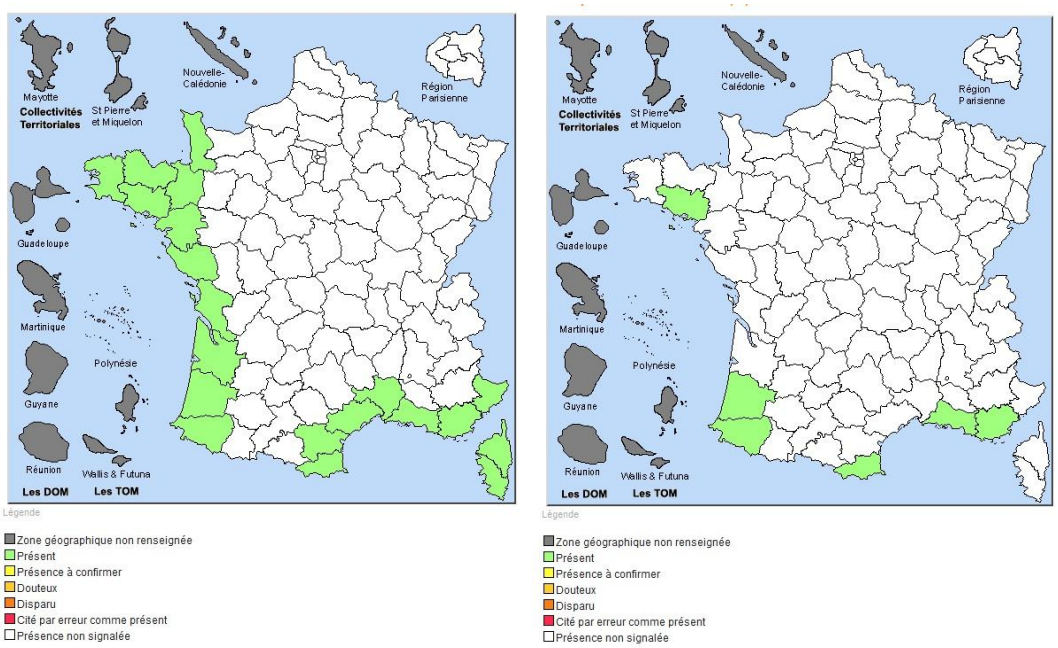

Figure 3. Geographical distribution of *Carpobrotus edulis* (on the left) and *C. acinaciformis* (on the right) in France. Source: http://www.tela-botanica.org/eflore/BDNFF/4.02/nn/14652/chorologie

- **United Kingdom and Ireland:**

Carpobrotus edulis is mainly established along the south-western coasts of England, Wales, Channel Isles (Guernsey) and western Ireland (see figure 4). Some scattered populations are also found in Scotland, though in a much lesser extent than elsewhere in the country due to local harsher winter conditions. *C. acinaciformis* is only found in West Cornwall, Isles of Scilly.

Figure 4: geographical distribution of *Carpobrotus edulis* in the United Kingdom and Ireland. Source: https://secure.fera.defra.gov.uk/nonnativespecies

- **The Netherlands**:

5 specimens of *Carpobrotus edulis* have been found at the western tip of Overflakkee in January 1991. No other specimens were recorded in the wild since then (Waarneming.nl, see figure 5).

Figure 5: geographical distribution of *Carpobrotus edulis* in The Netherlands.
Source: http://waarneming.nl

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 potential pathways of entry in Belgium are identified: voluntary introduction for ornamental or soil stabilisation purpose and dispersion from neighbouring countries (particularly from France where invasive populations are established) by endozoochory (seed transport by animals after ingestion). Hydrochory (seed transport by water current) should also be considered and may play a role in *Carpobrotus spp*. dissemination since it cannot be excluded that seeds/fruits from Northern France or Southern England aren't transported by sea currents to the Belgian or Dutch coast.

ENTRY IN BELGIUM

Potential pathway of entry in Belgium (and neighbouring countries) is voluntary introduction of individuals for ornamental or soil stabilisation purpose. If planted in adequate ecological/climatic conditions, subsequent endozoochoral or hydrochoral dispersion of individuals (originally planted in Belgium or neighbouring countries) can be considered as a secondary pathway of entry.

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

Carpobrotus edulis is slightly agamospermic, completely self-fertile, slightly preferentially self-compatible, and experiences no inbreeding depression (Vila *et al.* 1998; Suehs *et al.* 2004b). "Active growth of *C. edulis* occurs primarily along the main axes, although lateral branches may also grow, particularly following death of the apical meristem of the main axis. The plant shows a vegetative propagation by runners (rooting at nodes). An individual branch can elongate more than 1 m in a year. Branches tend to grow over each other, resulting in the accumulation of up to 40 cm of live and dead plant material. Stems exhibit vine like growth and can crawl over shrubs, fences and other obstacles. Growth speed of *C. affine acinaciformis* was studied by Sintes *et al*. (2007) and it has been demonstrated that population expansion rate can reach of 0,3 m/year. Rooting occurs at nodes in contact with the soil surface (D'Antonio, 1990a). The plant is readily cloned by rooting stem fragments that contain at least one node.

The fleshy, indehiscent fruits provide food for deer, rats, rabbits etc. and seed germination is enhanced by the ingestion of fruits. Ungerminated seeds remain viable for at least 2 years (D'Antonio, 1990b).

Pollination occurs by unspecialized generalist pollinators and although it appears to be usually limited (http://www.europe-aliens.org), the presence of *Carpobrotus spp*. seems to affect pollinator networks in invaded areas. The showy flowers of these species are indeed highly attractive for pollinators in comparison to less conspicuous flowers of native species. As a result of this, reduction of the potential pollinisation of native species facing a *Carpobrotus s*pp. invasion has been subject of concern (Bartomeus & Vila, 2008).

B/ Climatic requirements[2]

Carpobrotus spp. occurs in warm temperate to dry climate. Resistant to drought but highly sensitive to frost (-4°C (FCBN 2009) being the extreme temperature of resistance below freezing point).

C/ Habitat preferences[3]

C. edulis is associated to coastal habitats and can be found on cliffs, sand-dunes, salt marshes and coastal sage scrub, ledges and shores, tundra habitats, chaparral, broadleaved deciduous woodland, coniferous woodland, inland cliffs. The species can also flourishes inland on roadsides and railway lines, outcrops and regularly or recently cultivated agricultural, horticultural and domestic habitats as well as constructed, industrial and other artificial habitats.

C. edulis needs well-drained soil, full sun exposition and room to spread. It tolerates drought and wind but not high nitrogen levels, nor frost (Prescott and Venning, 1984; Webb et al., 1988; GISP, 2008). Growth is slightly enhanced by low seawater concentrations but reduced at high salinity (Weber and D'Antonio, 1999). The plant grows both in moist and dry sites.

D/ Food habits[4]

Not applicable.

E/ Control agents

The species are sensitive to frost (see chapter 2.1.4.B). Herbivory by mammals may cause significant seedling mortality, but once established it is not affected by herbivory or competition. Rodents or insects may be important seed predators or secondary dispersers; seeds are damaged by granivorous rodents.

F/ Establishment capacity in Belgium

Climatic rigor is the main factor limiting *Carpobrotus spp*. establishment in most part of Belgium. Along the Belgian coast the mean temperature does not show extreme freezing events (average temperature in January and February being above 0°C), potential establishment of *Carpobrotus spp* is therefore not unlikely.

[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.

[4] For animal species only.

Elsewhere, being sensitive to frost most introduced plants die when temperature reaches -4°C. Global warming could, on the mid-term enhance colonisation of *Carpobrotus spp.* populations from northern France.

While taking into account the IPCC scenario predicted for Belgium, we have not found information on the projected number of ice days in the mid-term future. To solve this lack of information, we made the hypothesis that there is a linear correlation between number of ice days and average minimal temperature in January. The expected increase of harshest winter temperature (in January) will, depend of the different IPCC scenario, ranging from 0.8°C to 3.2°C (Marbaix & van Yperzele, 2004).

If the hypothesis "*number of ice days and frost days are linearly correlated to January minimum average temperature"* is correct, we can expect that, with a raise of average January temperature of 3.2°C in the Ardennes in 2050, winter conditions in Saint-Hubert (554 m) will be similar to those ones observed in Brussels actually. In such a prediction (which is the most extreme evolution in ICPP scenario), a strong decrease in the number of frost days is to be expected. This can conduct to a release of the climatic limiting factor for *Carpobrotus spp.* establishment in Belgium. If we now consider the less extreme evolution in ICPP scenario for 2050, which would be an elevation of temperature of 0,8°C in Saint-Hubert, only a limited decrease in the number of frost per year would be observed. This implies that climatic limiting factor for *Carpobrotus spp*. establishment would still play a significant role in the (near, 2050) future.

However, even without extreme global warming effects, the coastal area is potentially an ideal habitat for the establishment of the species as it has happened in England or the North Atlantic coast of France with similar climatic conditions.

G/ Endangered areas in Belgium

When climatic and environmental requirements are met*, Carpobrotus spp*. shows a high invasion potential in the dune ecosystems (e.g. as in the Belgian coastal area in case of rising winter minimal temperatures due to global warming). Therefore most of the dunes systems that are protected in Belgium (e.g. Westhoek, het Zwin or Kalmthout) can be considered as areas potentially subject to invasion.Establishment capacity in the Belgian geographic districts:

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

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

ESTABLISHMENT CAPACITY AND ENDANGERED AREAS IN BELGIUM

Currently the risk of establishment of the species is likely. As observed in other neighbouring countries with similar climate conditions, *Carpobrotus* spp. could readily invade suitable habitats (such as dune ecosystem along the coast or Kalmthout) as long as temperatures remain in the tolerance range of the species (future climate change may enhance further southern populations expansions).

2.1.5 Dispersion capacity

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

A/ Natural spread

The fleshy, indehiscent fruits of *Carpobrotus spp*. provide a water and energy-rich food source for various mammals (e.g. deer, rat, rabbit) and are therefore subject to endozoochory. This way of dispersion can be effective over distances exceeding 1 kilometer. Moreover, seed germination is enhanced by the ingestion of fruits by animals. Ungerminated seeds remain viable for at least 2 years, which allows the formation of a soil seed bank. The uneaten fruits remain on the plants for several years, constituting a type of canopy seed bank *(*http://www.europe-aliens.org*)*

It has been observed that rats and rabbits (also considered as locally invasive species) are the primary seed dispersers of *Carpobrotus spp*. on offshore islands in southeast France. In return *Carpobrotus* provides a water and energy rich food for the rats and rabbits during the dry season, indicating a clear case of mutualism between the invaders (Bourgeois *et al*. 2005).

Birds do not eat the fruits but gulls can assist spreading of the plant by taking vegetative fragments as nesting material (Preston and Sell, 1988).

B/ Human assistance

Carpobrotus edulis has been widely used as a soil binder for erosion control in many countries. It is also planted as an ornamental plant or as ground cover on embankments in coastal districts, for fruit and as a medicinal plant in folklore (GRIN, 2006).

In Belgium it is not a common plant in plant shops but international online stores propose stems (sent by mail) for an attractive price. One advertisement found on the Internet (see here after) shows how difficult it is to find the plant in Belgium and how difficult it is to keep it alive under non-optimal climatic and environmental conditions (e.g. Liège).

Déposé par **chris XXXX**
le Dimanche 04 Mars 2012
Bonjour, Je recherche un ou plusieurs plants de carpobrotus edulis, si plusieurs coloris de floraison, avec une préférence pour les mauves et oranges, elle est aussi appelée griffe ou doigt de sorcière; à envoyer en Belgique à Liège, payement d'avance de la plante et des frais d'envoi. Plante introuvable en Belgique, j'en avais ramené du Midi de la France quand j'étais routier, je l'ai perdue à cause de fortes gelées. Contact ici > chris XXXX ou via mon mail chrisXXXX@hotmail.com D'avance, un grand merci.

Source : http://www.graines-et-plantes.com

DISPERSAL CAPACITY
Human introduction for ornamental or ground stabilization purpose is the main driving force of *Carpobrotus* invasion. Various mammals may feed on fruits and disseminate seeds by endozoochory (up to several kilometres away).

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

Under suitable environmental conditions, *Carpobrotus* spp. form impenetrable mats and outcompete sand-dwelling native plants (such as *Ammophila arenaria*, *Eryngium maritimum*, orchids). Suehs et al. (2004a, b) conclude that both *C. edulis* and *C. affine acinaciformis* should be considered as harmful invasive plants posing severe threats to native plant communities and ecosystems in the Mediterranean Basin, the former because of the flexibility of its mating system and high seed production, and the latter because of its strong clonality, high hybrid vigour, and potential for continued introgression (Suehs *et al*., 2004). Ultimately, competition for light and water are the main cause of biomass, lifespan and fecundity decline of most plants sharing the same biotope.

A genet of a clonal plant often has ramets persistently interconnected by living tissue capable of supporting the exchange of materials. This condition is known as physiological integration (Chesson & Peterson, 2002). *Carpobrotus edulis* displays such a physiological integration that improves its survivorship and growth of apical ramets. In terms of survivorship, the benefit of integration is even greater under high competition. This can therefore be considered as an important factor in the invasiveness of *C. edulis*, both in open space and in direct competition with the native plants (Roiloa et al., 2010).

Indirect competition is also reported. Carpobrotus species are able to change soil biotic conditions affecting the growth and also seed germination capacities of other dune plants (Conser *et al*. 2009; de la Peña *et al*. 2010).

The capacity of *Carpobrotus spp*. to switch to crassulacean acid metabolism (CAM) when subjected to drought or salt-stress (Schmalzer and Hinkle 1987) could be a considerable competitive advantage against other native species.

Native plant seed production may also be altered when *Carpobrotus* spp. become dominant. Jakobson *et al*. (2008) studied the effect of pollen transfer by shared pollinators between Carpobrotus spp. and native plants. Although this study showed that invasive pollen had probably little impact on the native community, it was highlighted that pollination interaction may change with plant abundance and the study provided evidence that pollen transfer from *Carpobrotus* spp. to natives species does occur and have the potential to affect seed production.

B/ Predation/herbivory

Herbivory by mammals may cause significant seedling mortality, but once established it is not affected by herbivory or competition. Rodents or insects may be important seed predators or secondary dispersers; seeds are damaged by granivorous rodents (http://www.europe-aliens.org).

C/ Genetic effects and hybridization

At an early stage of development, it has been demonstrated that hybrids between *C. edulis* and *C. acinaciformis* show a higher competitivity than their parents (Suehs, 1999; Suehs *et al*., 2001, 2003). *Carpobrotus* being naturally demanding regarding water availability, these hybrids may alter the water balance of the invaded substrate and enhance competition with native species.

D/ Pathogen pollution

No specific pathogen reported.

E/ Effects on ecosystem functions

Among many other invasive species *Carpobrotus spp*. are some of the most threatening in regions of the world characterized by a Mediterranean climate because of their high covering potential inducing a rapid competition with native vegetation (D'antonio 1993; Vilà et al. 1998; Médail 1999; Suehs et

al. 2001). In fact, *Carpobrotus edulis* interacts both directly by suppressing the growth and establishment of other plants and indirectly by altering soil chemistry (Conser & Connor 2009). Edaphic characteristics are subject to perturbation following *Carpobrotus* invasion; in particular low soil pH. *Carpobrotus* also influences nutrient dynamics, increasing soil nitrogen and organic carbon contents (D'Antonio 1990a, D'Antonio and Mahall, 1991), reduce nutrients availability and water balance (*Carpobrotus* being highly demanding towards superficial humidity) (D'Antonio & Mahall 1991). Modifications of soil factors (organic matter content, pH and salinity) in *Carpobrotus* invaded sites was recently investigated by Santoro *et al.* (2011). By comparing effects of growing populations of *C. edulis* in different types of dune system and different native vegetal cover, differences between invaded and non-invaded plots for nitrogen content, organic matter content and pH was measured in foredune habitats and none on fixed dunes. Thus, they found distinct responses of soil factors to *Carpobrotus* invasion depending on the habitat. Pioneer habitats with very poor soils are more sensitive to invasion probably because the production of litter by *Carpobrotus* is considerably higher than for native species. *Carpobrotus* invasion is therefore more likely to affect the parameters of the soil in pioneer habitats (such as a foredune zone) compared to more complex, structured dune system (Santoro *et al.,* 2011)

Residual effects of *C. edulis* infestation has been tested on the west coast of the United States and lead to lower germination, survival and growth rate as well as lower reproduction succes of native plants such as *Gilia millefoliata*, a rare dune annual (Conser & Connor 2009). The main effects of *C. edulis* presence is (as already mentioned) a lower soil pH and increased organic content due to the recalcitrance of tissue to decomposition. This later phenomenon may have evolved as a mechanism to facilitate recolonization and invasion (Conser & Connor 2009).

In sand-dune ecosystem of Portugal, however, it has been demonstrated that the success and impacts of *C. edulis* on native community are habitat-dependent and context-specific (Maltez-Mouro *et al*. 2010). The effects of climate on the community structure variables are shown to be on average three times stronger than those of *C. edulis* (at least when *C. edulis* does not reach large abundance). Indeed in their study, Maltez-Mouro *et al*. (2010) did not observe large abundances or exert negative impacts of *C. edulis* on native communities to the extent expected providing evidence of a strong resilience to the impacts of invasion in the studied ecosystem.

ENVIRONMENTAL IMPACTS

Large populations of *Carpobrotus spp*. outcompete drastically sand-dwelling native plants (particularly for light and water) and alter soil chemistry (pH and nitrogen equilibrium) as well as nutrients (organic carbon content). Hybrids among *Carpobrotus* species are very vigorous and may lead to intensified invasion.

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).

The main economic impact of *Carpobrotus spp*. invasion in Belgium would be the cost of eradication measures if the plant became widely spread. Previous action plans undertaken on several European islands (e.g. Minorca) highlights the fact that early action in controlling these species minimizes long term impact and cost.

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

A potential beneficial use of the plant in term of human health and well-being has been reported. Custódio *et al.* (2011) mention antioxidant, metal chelating and anticholinesterase activities of methanol extracts from *Carpobrotus edulis.* They also report a preliminary chemical screening, total contents of phenolic compounds in the extracts and the fatty acid profiles of the species. *Carpobrotus edulis* has dual anti-cholinesterase activity against both acetylcholinesterase and butyrylcholinesterase. With a high content of phenolic compounds, *Carpobrotus edulis* is a candidate species for future studies on novel and alternative therapies for the treatment of neurological disorders associated with low levels of acetylcholine in the brain.

Carpobrotus spp. can also open interesting perspectives regarding the search of new anti-cancer (Ordway *et al.* 2003) and anti-bacterial molecules (Watt *et al*. 2001).

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 major potential pathway of entry in Belgium (and neighbouring countries) is voluntary introduction of individuals bought from foreign countries nursery businesses (most likely sold through the Internet for ornamental purposes). Introduced populations can become invasive if planted in adequate ecological/climatic conditions and subsequent dispersion of individuals from these populations (originally planted in Belgium or neighbouring countries) can be considered as a secondary pathway of entry.

3.2 PREVENTIVE ACTIONS

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

(i) Prohibition of organism importation, trade and holding

Several actions can be undertaken in order to limit *Carpobrotus spp*. introduction in non-native countries:

- **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. edulis* and other 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 *Carpobrotus spp*. 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 industry and the general public.

ISCP for horticultural professionals	ISCP for the general public
1.Be informed about Belgian alien species list	1.Be informed about Belgian alien species list
2.Stop selling and/or planting invasive alien species	2.Avoid buying and plant alien species
3.Spread information about invasive alien species to customers and the general public	3.Choose in priority non-invasive native plant as an alternative to alien species
4.Promote the use of alternative, non-invasive plants	4.No dumping vegetal residues in nature, streams and ???
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 are abiding by the codes.

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

Avoid planting *Carpobrotus spp*. as ornamentals and dumping plant debris in the wild. Prescribed burning (T° > 100°C) can reduce seed bank.

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)?

The species is very conspicuous and any population establishing itself can easily be detected even at early stages of invasion.

(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.

Three means of controlling *Carpobrotus spp.* invasion are usually proposed and readily available (physical, chemical and biological):

- **Physical**

  At early invasion stage, manual methods appear to be the most effective and cost-efficient means of controlling *C. edulis*. Albert (1996; in Pier, 2005) recommends: "Hand-pull individual plants and remove any buried stems. Mulch to prevent re-establishment. in particular situations, when large mats start to form, it can be removed by “rolling them up like a carpet". In most cases though *Carpobrotus spp*. are deeply rooted, and the weight of a single patch of just a few meters in diameter can weigh up to 100 to 200 kgs (if fully grown ; E. de la Peña, pers. comm.). So in terms of personal allocated to the task, removing mats manually usually reveal itself as a herculean task.

  During eradication process, it is important to remove any *C. edulis* remains, as any left in place become a focus of regeneration, due to the large number of seeds which survive in the fruit for a long time (Fraga *et al*. 2006). After removal, secondary invaders may take advantage the opened areas. For sand dunes, seeding native grasses has not been effective.

  No mechanical control options (i.e. use of machinery) are recommended. This reflects the sensitive nature of the environment on which the species is known to impact.

- **Chemical**

  A broad spectrum herbicide such as glyphosate or 2,4-D plus 2,4-DP products (2,4-dichlorophenoxyacetic acid plus 2-(2,4-dichlorophenoxy) propionic acid) is recommended to control this species (Kelly & Maguire, 2009; PIER, 2005). The use of these chemicals is complicated by the environment and the protected habitats in which this species colonizes. Careful consideration and techniques to minimize the amount of chemical utilized is required. It may be more appropriate to employ this chemical control after manual removal of the plant. It is assumed that broad spectrum herbicides would kill *C. edulis* but they may also impact adjacent vegetation. Chlorflurenol, a morphactin, has been used to reduce growth of *C. edulis* along roadways (Hield and Hemstreet, 1974; in Schmalzer and Hinkle, 1987).

- **Biological**

  The options for biological control are currently limited, as the pathogens which attack *C. edulis* are not specific to it. *Verticillium wilt* can cause considerable damage (McCain *et al.* 1974), but using it could cause problems as it also attacks commercial crops (Schmalzer and Hinkle, 1987). Suehs *et al.* (2004b) state that a constraint on seed production or germination

would be the most efficient way to control *C. edulis* on a long-term basis, if possible, due to its high success in these domains. Two introduced scale insects (*Hemiptera*) caused widespread mortality of *Carpobrotus edulis* plantings in California in the 1970s (Donaldson *et al.* 1978). As a result the California highway Department introduced natural enemies to control iceplant scale (Tassan *et al.* 1982). Nonetheless, scale insects have been observed to cause death of clones in California and could be more widely promoted in natural settings (D'Antonio 2008).

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

Chemical eradication of any invasive species with a broad spectrum herbicide will inevitably have consequences on native species sharing the environment. Being non-specific, these products will in most cases destroy the remaining native and sometimes endangered species populations of the sensitive dune ecosystem. Moreover most of these chemicals are proven to be extremely toxic to aquatic plants and wildlife. It is therefore essential that the users fully comply with the Pesticide Product Label especially for use in or near water-bodies (as it is usually the case on *Carpobrotus spp*. colonies*).* Mists from herbicide sprays on hot days can drift in high winds and may impact on non-target plants and animals from greater distance and careless washing of equipment can contaminate soil, drinking water, surface water and ground water. Managers should therefore always consider techniques to minimize the volume of herbicides allowed to enter into the environment.

Biological eradication using grazer animals may also lead to collateral damage on native species by unusual trampling (particularly disturbing on soft substrate) or grazing.

Once *Carpobrotus spp.* has been removed, it is important to monitor for recovery of the ecosystem and to ensure that the target species or other invasive species do not recolonize the cleared site. Seeds of *Carpobrotus spp.* remain viable for long periods of time so after removal of *Carpobrotus spp*. carpets there is a high risk of re-colonization even after a few years. Secondary plant invaders can also take advantage of opened areas, spreading rapidly and impeding restoration efforts in coastal dune habitats. *C. edulis* leaves behind a layer of debris of dead and decaying organic matter that accumulates under the plant. This tends to be left behind after *C. edulis* is removed and has the effect of altering soil pH and may have a negative effect on native species seed germination. Within the debris are often the dormant seeds of other competitive native grasses less sensitive to *C. edulis* effects. These can sprout excessively after *C. edulis* is removed, benefiting from the accumulation of nutrients in the area that *C. edulis* has facilitated (D'Antonio, C. 2008).

Post removal considerations: to avoid any further rapid re-colonization, it may be best to selectively remove *C. edulis* to ensure that some is left behind to stabilize the soil and minimize sand movement into the area. Once the area has been restored to a more natural community, the remaining *C. edulis* can be removed and that area restored in turn (GISD, 2009). This phased approach will ensure the long term sustainability of the site.

(iv) Could the species be effectively eradicated at early stage of invasion?
Yes, as long as proper measures are taken during the eradication process and that long terms measures and monitoring are carefully respected (to detect any secondary growth of the target species or subsequent invasion of another opportunistic species).

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

Carpobrotus spp. is an aggressive exotic complex of species that has invaded many coastal plant communities in Europe. It is widely considered as a super-invader that produces edible fruits with a lot of seeds, creates a huge and highly viable seed bank, has an alellopathic effects on native flora, changes soil properties, grow clonally, resist to drought, and finally spread in ever-larger mats across the surface of the soil or sand. In non-native environment *C. edulis* outcompetes and in many cases, smothers other species (vegetal and sometimes animal), often creating near monocultures over extensive areas.

If *Carpobrotus spp.* becomes widely spread or the introduction occurs in several points then attempts of population control can rapidly become a very difficult task and a serious issue.

Few cases reported as successful stories (from Mediterranean areas) are listed here under. These cases, although successful should be taken with extreme caution or a degree of skepticism. The fact that there are only a few of these successful records could indicate a positive biased (only successful stories tend to be reported). Most importantly, at the end, eradication is never guaranteed on the long term. These cases of "eradication" are presented to illustrate how difficult is to deal with the species at a large scale in order to bring the population to an acceptable level (but rarely to a total eradication).

- **Minorca Is.**
  Early attempts at controlling *Carpobrotus edulis* in Minorca began in the late 1990s, with the aim of eradicating the plant from Favaritx (in the north-east of the island). This was not achieved due to landowner opposition. Eradication measures were simultaneously carried out in the east of the island by the local NGO Grup d'Ornitologia Balear i Defensa de la Naturalesa. Subsequent to these early attempts, further preparatory measures were carried out to enhance the success of further efforts. A detailed cartography regarding the distribution of the plant was undertaken, and experimental methods investigated to determine the best means of eradication and restoration. These revealed that the plant covered 25.8ha of the island, and that the most efficient eradication method was manual removal. Eradication was finally undertaken between 2002 and 2005. An awareness campaign was also launched, to ensure its ongoing success. Alternative plants for gardening were suggested. Today the plant is restricted to two zones in the north east of the island, due to opposition of landowners to its removal (Fraga *et al*. 2006).

- **Ramla I-Hamra**
  Carpobrotus edulis was eradicated from Ramla I-Hamra, Malta in 2001. The invasion was in the early stages when the eradication was carried out by the former Environment Protection Department, using manual methods (IUCN, 2005).

- **Ramla tat-Torri**
  Carpobrotus edulis was eradicated from Ramla tat-Torri, Malta in c.1997/99. The invasion was partly extensive but not considered serious at the time of eradication. The eradication was carried out by the former Environment Protection Department, and involved manual methods. It caused some initial disturbance, but also contributed to the expansion of the Centaureo-Ononidetum fixed dune community (IUCN, 2005).

RISK MANAGEMENT SUMMARY

Voluntarily introduced for ornamental reasons (or possibly dispersed by endozoochory or hydrochory), *Carpobrotus spp.* are widely considered as super-invaders that outcompetes native flora, and alters biotic and abiotic soil characteristics.

Once established and widely spread *Carpobrotus edulis* and *C. acinaciformis* populations form dense mats that become very difficult to control and nearly impossible to eradicate.

Means of control include manual removing by "hand-pull" (though not efficient for large populations), and the use of chemicals such as glyphosate 2,4-D or 2.4-DP based herbicide (chemical control is generally difficult because of existing legislation concerning their use in natural environment). The use of pathogen (such as *Verticillium wilt*) or control agents (e.g. scale insect) are usually not recommended because of their characteristic of being non specific and the probability to cause uncontrolled effect on native plants and/or crops.

Increasing public awareness on risks of *Carpobrotus spp*. purchasing and planting remains the most effective mean of control of these species. The practical control options should focus on prevention.

Preventive actions should lead to a total ban of *Carpobrotus spp.* trade 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 *Carpobrotus spp.* introduction (and subsequent possible dissemination and invasion).

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