Nederlandse Voedsel- en Warenautoriteit
Ministerie van Landbouw, Natuur en Voedselkwaliteit

> Return address PO Box 43006 3540 AA Utrecht

To the Director of Nature of the Ministry of Agriculture, Nature and Food Quality

Advice of the Director of the Office for Risk Assessment and Research concerning the

risks of Crassula helmsii for biodiversity, ecosystem services and other social values in the Netherlands

Office for Risk Assessment & Research

Catharijnesingel 59
3511 GG Utrecht
PO Box 43006
3540 AA Utrecht
www.nvwa.nl

Contact

T +31 (0)88 223 33 33
risicobeoordeling@nvwa.nl

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Background

Crassula helmsii, also known as Australian swamp stonecrop or New Zealand pygmyweed, is a perennial swamp and water-based plant that originated in Australia and New Zealand and is not native to the Netherlands. The plant is sold for use in aquariums and ponds.
Wild Crassula helmsii was first observed in the Netherlands in 1995. Since then, it has been observed in more locations (NDFF, 2020), including in nature conservation areas. The plant competes with other plants. Eradication measures have been largely ineffective and so far have only successfully eliminated small infestations in isolated bodies of water (Van der Loop et al., 2018). The plant is considered an invasive species in a variety of European countries (Robert et al., 2013).

As a result of these developments, the Office for Risk Assessment & Research (BuRO) at the Netherlands Food and Consumer Product Safety Authority (NVWA) initiated a study to examine the risks posed by Crassula helmsii. At the time, no scientific risk assessment had yet been performed for the Netherlands. The main question of this study was as follows:

"What are the risks of Crassula helmsii for biodiversity, ecosystem services and other social values in the Netherlands?"

Approach

In order to answer this question, BuRO commissioned the Dutch Botanical Research Foundation (FLORON) to perform a risk assessment in compliance with the criteria[1] for submission to the European Union list of invasive alien species of concern. For this purpose, the Harmonia+ protocol (D'hondt et al., 2014) was used, which specifies that the assessment and classification of the risks must be conducted by a team of experts (in this case, the six writers of this assessment). In addition, FLORON also examined the costs and benefits of Crassula helmsii.

The results of the risk assessment have been published in the report entitled *'Risicobeoordeling van Watercrassula (Crassula helmsii) in Europa'* ['Risk

[1] https://eur-lex.europa.eu/legal-content/NL/TXT/PDF/?uri=CELEX:32018R0968&from=EN

Assessment of Australian swamp stonecrop (Crassula Helmsii) in Europe'] (Van der Loop et al., 2020).
Unless otherwise specified, the information in the advice at hand originated from this risk assessment.

With regard to the trade of this species, the risk assessment only describes whether or not the sale is regulated in the various EU member states. On 5 October 2020, BuRO conducted a scan of the internet to investigate possible Dutch trading of Crassula helmsii and gain insight into the extent of sales of the plant in the Netherlands. For this purpose, Google searches were conducted (examining the first 30-40 results) using the search terms 'Crassula helmsii', '*watercrassula*' (Australian swamp stonecrop), *'waternaaldkruid'* (New Zealand pygmyweed) and 'Crassula recurva' in combination with the search term *'kopen'* (buy). Furthermore, searches via Google Scholar (examining the first 30-40 results) were also conducted using the search terms 'benefits', 'economic value' and 'environmental services' in combination with the term 'Crassula helmsii'.

Findings

- Crassula helmsii is distributed throughout the Netherlands, particularly in more elevated sandy soils. Wild Crassula helmsii was first observed in 1995 and the number of sightings has been increasing year on year.
- The plant propagates via vegetative reproduction. Tiny fragments of stem are potentially capable of growing into fully grown plants. Its germinating power in its original dispersal area in Australia is very low and the vitality of the seeds also appears to be low in areas outside its original environment. However, when an extremely large quantity of seeds are produced, it is possible that the seeds can also contribute to the spread of Crassula helmsii.
- The plant is sold as an oxygenating plant for ponds and aquariums. Several years ago, a 'voluntary' ban on the cultivation and sale of Crassula helmsii was introduced within the framework of the Aquatic Plants Agreement[2] (*Convenant waterplanten*), although this agreement was effectively scrapped when Directive (EU) No. 1143/2014 on the prevention and control of the introduction and spread of invasive alien species[3] came into force.
- The plant has entered the Dutch ecosystem via active introduction into or disposal of plants from garden ponds and aquariums.
- There are many ways in which human activity further promotes the propagation of Crassula helmsii. Loose stem fragments can be spread by land transport, machines, sailing vessels, shoes or fishing gear.
- Natural spread can also occur via stem fragments floating in water. Furthermore, the plant can be spread by animals, e.g. via consumption and excretion of fertile plant parts by waterfowl, livestock and other animals, or via body parts of animals to which the plant becomes attached, e.g. the paws.
- Large areas of Europe are climatologically suitable for the plant, particularly the areas with a more Atlantic climate.
- Crassula helmsii is not highly selective when it comes to location. The plant prefers standing water or slowly flowing waters and the banks of such bodies of water. The plant grows in systems featuring both sandy and clay soil, both of

[2] Government Gazette, 2010, no. 11341. Aquatic Plants Agreement https://zoek.officielebekendmakingen.nl/stcrt-2010-11341.html
[3] http://eur-lex.europa.eu/legal-content/NL/TXT/PDF/?uri=CELEX%3A32014R1143&from=NL

which are widely available throughout the Netherlands. The plant predominantly establishes itself in pioneer situations that occur in many areas due to natural processes or human intervention. Severe frost and prolonged dry periods hinder the plant's growth.

- Crassula helmsii can establish a dominant presence both in areas rich in nutrients and areas in which nutrients are scarce. In relatively nutrient-poor ecosystems such as fens and dune ponds, the plants remain small and have little ability to compete. In such environments, Crassula helmsii can only become dominant if very few native species are present. However, when nutrients are available in significant quantities, Crassula helmsii grows quickly and is capable of overrunning other species. The provision of nutrients via atmospheric deposits of nitrogen and the eutrophication of surface and ground water by carbon, nitrogen and phosphorous from agricultural activities and waterfowl droppings can contribute to the proliferation of Crassula helmsii.
- Rapid growth of Crassula helmsii can result in the plant dominating its environment and forming an impenetrable layer of vegetation on river beds, banks or on the surface. Thick Crassula helmsii vegetation displaces native plants and animals. When the plant establishes itself in areas containing European protected species (Annex IV of the EU Habitats Directive), they can threaten these endangered plants. Crassula helmsii also poses a threat to protected animal species.
- Propagation of Crassula helmsii in natural ecosystems can result in fundamental changes. The plant's presence affects the hydrology (e.g. by blocking the flow/drainage of water, accelerating evaporation of bodies of water) and the oxygen content of the water (lack of oxygen due to the decomposition of plant residue). The lack of oxygen in the water and the accumulation of organic matter from dead plant parts on the bed cause mobilisation of phosphate and subsequently eutrophication, which can also result in sulphide being released. This has a negative effect on the biocoenoses in the water.
- In wet or moist pioneer environments, Crassula helmsii can be invasive. Following eradication, these locations can easily become infested again. Furthermore, Crassula helmsii is not very selective when it comes to location, and unlike many native species, it is suited to prolonged dry periods.
- No effects on human health, agricultural crops or farm animals have been reported.
- Combating a species is extremely difficult when even the smallest stem fragment can develop into a fully grown plant. In order to be effective, the measures must be extremely thorough and years of aftercare will be required to truly eradicate the species. It is especially difficult to eliminate the plant as many of the control measures result in ideal conditions for regrowth or new establishment of the plant. Eradication only appears possible if the location can be drained. If drainage is not possible, then the only remaining options are to control the growth or to do nothing at all.
- Any measures to combat Crassula helmsii must be tailor-made. When selecting the most suitable measures, you must examine the characteristics of the infestation, the infected location, and in some cases, the surrounding area. Control measures will therefore be costly.
- In 2018 and 2019, the provinces of Friesland, Drenthe, Gelderland, Utrecht, Noord-Holland, Noord-Brabant and Limburg spent a total of €4,320,000 on control measures focusing on a limited amount of area with relatively high costs. Terschelling is an outlier, with the province of Friesland contributing €3,370,000 to a €5 million project. For 2020, measures are anticipated in

Noord-Holland, Zeeland and Noord-Brabant at the very least, with Noord-Holland and Zeeland expecting costs of at least €450,000 between them. It is probable that additional measures will also be required in Friesland, Drenthe, Gelderland and Utrecht. The measures in Friesland are expected to cost €2 million. (House of Representatives, 2020)

- No data is available on the benefits of Crassula helmsii. The plant is sold in the Netherlands via a few websites, often under the name 'naaldkruid' (*Crassula recurva*). The now-defunct Netherlands Aquatic Plants Agreement (2010) included Crassula helmsii in Annex 1, meaning that the plant was no longer sold to consumers by the partners participating in the agreement.[4] The total economic value of the plant is estimated to be low and plenty of alternative oxygenating plants are available.
- The plant is considered invasive in multiple European countries and laws prohibiting or regulating the sale and trade of the plant are in force in the United Kingdom, Switzerland, Denmark, Poland and Spain.

Answer to the main question
"What are the risks of Crassula helmsii for biodiversity, ecosystem services and other social values in the Netherlands?"

Chance of establishment and spread
Crassula helmsii has already established itself in the Netherlands and the likelihood of accidental or intentional new introductions of the species is high. The plant is sold as a pond and aquarium plant and waste plants are often dumped, meaning that Crassula helmsii are regularly found in fens and ponds near residential areas together with other aquarium and pond plants. Further spread from garden ponds and parks via animals (e.g. amphibians and birds) is highly likely. The natural dispersion capacity of Crassula helmsii has been evaluated as high with high certainty. Very small stem fragments are still viable plants and they can be spread via the natural flow of water. Spreading via waterfowl and other animals has also been observed. The frequency of secondary spread of Crassula helmsii via human activities has also been evaluated as high with high certainty. The plant can easily be transported via groundwork, groundwork materials, mowing equipment, vehicles, boats, shoes and fishing gear.

Effects
Based on the aggregated evaluations for the six questions about biodiversity and ecosystems (the category 'environment' in the Harmonia$^+$ protocol), the risk to biodiversity has been assessed as high with high certainty. These effects have been deemed irreversible as substantial and extremely costly measures are required in order to eradicate the species fully from ecosystems. Crassula helmsii regularly forms thick masses of vegetation, which displaces native plants and animals. This can have a negative effect on plants, animals and habitats protected by the EU Habitats Directive. In pioneer situations, Crassula helmsii also hinders the establishment of native species as the plant is able to quickly occupy all of the available space under such circumstances. In undisturbed areas of vegetation, this effect is lessened.

[4] https://zoek.officielebekendmakingen.nl/stcrt-2010-11341.html#d8401e497

The likelihood of Crassula helmsii having a significant impact on the *integrity of ecosystems* as a result of changes to the composition of the living organisms and environmental factors is high with moderate certainty. If Crassula helmsii establishes itself in natural ecosystems, it can result in fundamental changes to these ecosystems and its physical and chemical composition. Effects on physical/chemical properties (such as light regime and oxygen content) are evident in view of the high productivity of this species, which often fully covers large parts of the ecosystem.

The effect on *ecosystem services* has been evaluated as neutral to moderately negative with moderate certainty. High densities of Crassula helmsii can reduce drainage and cause hydrological engineering structures such as culverts to become blocked. The likelihood of such effects is high, although the damage is reversible. Due to the thick density and displacement of native species, the amenity value of ecosystems is reduced.

Advice BuRO

To the Director of Nature of the Ministry of Agriculture, Nature and Food Quality

Take or encourage measures to combat establishment in new locations and further spread of Crassula helmsii, for example by:

- Preventing the trade and disposal of Crassula helmsii into nature.
- Proposing that the European Commission includes Crassula helmsii on the EU list of invasive alien species of concern.
- Providing information on the risks of the plant and opportunities to prevent further introduction and spread in the natural environment.
- Promoting early identification of and rapid responses to new isolated growth environments.
- Promoting knowledge development concerning effective methods to eradicate, control (including systematic management) and prevent further spread of the plant.
- To promote a code of conduct for hygienic practices among all parties who could contribute to preventing further spread.

Yours sincerely,

The Office for Risk Assessment & Research
Prof. Antoon Opperhuizen

SUBSTANTIATION

What is Crassula helmsii?

Crassula helmsii, also known as Australian swamp stonecrop or New Zealand pygmyweed, is a perennial swamp and water-based plant that originated in Australia and New Zealand and is not native to the Netherlands. On land, the plant forms climbing stems, while in the water, it develops stems that can grow either above water or completely under the water. Crassula helmsii is sold as an oxygenating plant for aquariums and ponds and has established itself in a variety of European countries, including the Netherlands. The plant is considered an invasive species in a variety of European countries (Robert et al., 2013).

Purpose and structure of the Crassula helmsii risk assessment

FLORON (the Dutch Botanical Research Foundation) has conducted a risk assessment in compliance with EU criteria. In accordance with these criteria, the investigators looked at the likelihood of introduction, establishment and spread as well as the effects on biodiversity and ecosystems, plant cultivation, domestic animals, public health and other effects, such as effects on infrastructure. The results of the risk assessment have been published in the report entitled *'Risicobeoordeling van Watercrassula (Crassula helmsii) in Europa'* ['Risk Assessment of Australian swamp stonecrop (Crassula Helmsii) in Europe'] (Van der Loop et al., 2020).

In the risk assessments and classifications of Crassula helmsii, the Harmonia$^+$ protocol was used. This protocol is a procedure for risk screening that is in line with the requirements of the European Commission. The positive effects that are not considered under this protocol are compiled in the information document and assessed in the component that considers effects on ecosystem services. The risk assessment was conducted by a team of six experts, who are also the authors of the risk assessment. Each expert completed the protocol, using the information document. During a workshop, a unanimous agreement was reached concerning all of the risk classifications and their degrees of certainty.

Risk: likelihood

Introduction

Outside Europe, it is likely that Crassula helmsii can only be found within its original dispersal area in New Zealand and Australia. The likelihood of introduction to the Netherlands from its original environment via natural spread is low with high certainty due to the substantial difference and the numerous natural and artificial barriers.

The likelihood of deliberate and accidental introduction by humans is high. Crassula helmsii is still imported into many EU member states (including the Netherlands) as an aquarium and pond plant and is still traded, although the sale of the plant has been banned in a number of EU member states. Waste plants are dumped in fens and ponds near residential areas. Further spread from garden ponds via animals such as amphibians and birds is highly likely.

Establishment
Crassula helmsii can be found in substantial volumes in multiple member states (including the Netherlands) and has spread widely within the EU. Wild Crassula helmsii was first observed in the Netherlands in 1995 and the number of sightings has been increasing year on year. Crassula helmsii is now a regularly observed plant in the Netherlands, particularly in more elevated sandy soils.

Crassula helmsii is not highly selective when it comes to location. The plant can be found in a large variety of freshwater bodies, from moderately acidic to lightly alkaline (pH from 4.4 to 7.8). This could be either standing water or slowly flowing water. Crassula helmsii can establish a dominant presence in both nutrient-poor and nutrient-rich environments. In nutrient-poor ecosystems, the plants remain small and have little ability to compete. The plant can only become dominant in these areas if very few native species are present. Long dry periods hinder the growth of Crassula helmsii, although the plants are resilient to such conditions: its tolerance of dry conditions is greater than many native species of aquatic and waterside plants.

Bodies of water are vulnerable to invasion by Crassula helmsii, as are areas in which few other plants are present, such as bare beds and open vegetation caused by developments in the natural environment or natural developments stemming from lower water levels over the course of the summer.

Spread
The likelihood of natural spread of Crassula helmsii has been evaluated as high with high certainty. This secondary spread is predominantly vegetative. Crassula helmsii reproduces vegetatively via meristem tissue (the stem cells that enable vascular plants to grow), which is present in every part of the plant. As a result, extremely small plant fragments can develop into new plants. Among other methods, the plants and plant fragments are spread via flowing water. Furthermore, the plant can be spread by animals, e.g. via consumption and excretion of fertile plant parts by waterfowl, livestock and other animals, or via body parts of animals to which the plant becomes attached, e.g. the paws. Based on the available data on spread patterns in the Netherlands, a distribution speed of 5-50km per year due to transfer via water or fauna seems realistic.

The likelihood of secondary spread of Crassula helmsii via human activities has also been evaluated as high with high certainty. The species has already spread widely across the Netherlands, it is still available for sale in various member states (including the Netherlands), it is present in many ponds and is still being planted. Due to all these factors, the likelihood of secondary spread or dumping of waste plant material in natural areas is high. The plant can easily be transported via groundwork, groundwork materials, mowing equipment, vehicles, boats, shoes and fishing gear. The frequency of human-caused spread over a distance greater than 50km within the EU is more than one per year. However, the relative importance of the variety of distribution mechanisms cannot be quantified.

Reproduction via seeds
The germinating power of Crassula helmsii in its natural habitat area in Australia is very low. In the past, it was believed that Crassula helmsii did not create fertile seed banks. However, lab research does not rule out reproduction via seeds in Western Europe. Most of the fruits do not contain seeds and the germination rate

is low. However, in heavily infested areas, the number of flowers is extremely high, and therefore the number of seeds capable of germinating can be high. The seeds can survive in a field through a normal winter.

Risk: effect

Biodiversity and ecosystems
The effect on biodiversity has been evaluated as high with high certainty. These effects have been deemed irreversible as substantial and extremely costly measures are required in order to eradicate the species fully from ecosystems. Crassula helmsii can establish a dominant presence both in areas rich in nutrients and areas in which nutrients are scarce. In relatively nutrient-poor ecosystems such as fens and dune ponds, the plants remain small and have little ability to compete. In such environments, Crassula helmsii can only become dominant if very few native species are present. However, when nutrients are available in significant quantities, Crassula helmsii grows quickly and is capable of overrunning other species. When Crassula helmsii dominates an area, it forms an impenetrable layer of vegetation on the bed, banks or surface of the body of water in question. Atmospheric deposits of nitrogen and the eutrophication of surface and ground water by carbon, nitrogen and phosphorous from agricultural activities and waterfowl droppings can contribute to the proliferation of Crassula helmsii.

Thick Crassula helmsii vegetation displaces native plants and animals. This can also negatively affect plants, animals and habitats protected by the EU Habitats Directive. For example, there have been reports of threats to flora and fauna such as the creeping marshwort (*Apium repens*), the fen orchid *(Liparis loeselii*), the floating water plantain (*Luronium natans*) and the natterjack toad (*Epidalea calamita*). In the UK, disturbances of the breeding process of protected amphibians has been reported, such as the northern crested newt (*Triturus cristatus*) and the palmate newt (*Triturus helveticus*). Vulnerable habitat types include waters with very low buffering capacity[5] and waters with low buffering capacity (H3110 and H3130), purple moor-grass meadows (H6410), humid dune slacks (H2190), wet heaths (H4010) and pioneer vegetations with white beak-sedge (H7150). Crassula helmsii can also grow in other types of waters and humid environments, although in these areas, it is rarely if ever a threat to biodiversity.

In pioneer situations, Crassula helmsii also hinders the establishment of native species as the plant is able to quickly occupy all of the available space under such circumstances. In undisturbed areas of vegetation, this effect is lessened.
It does not affect native species via predation, parasitism, hybridisation or transfer of parasites/pathogens.

The likelihood of Crassula helmsii having significant effects on the *integrity of ecosystems* as a result of changes to the composition of the living organisms and environmental factors has been estimated as high with moderate certainty. If Crassula helmsii establishes itself in natural ecosystems, it can result in fundamental changes to these ecosystems and its physical and chemical composition.

[5] Low buffering capacity means that the water has little ability to neutralise acid. In surface water, the buffering capacity is almost entirely determined by the quantity of bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) dissolved therein.

The presence and decomposition of Crassula helmsii results in fluctuating oxygen levels in water. Thick layers of Crassula helmsii form a barrier between the water layers, which blocks the transfer of oxygen to the deeper sections. The decomposition of large quantities of dead Crassula helmsii also results in a drop in oxygen levels. The lack of oxygen and the accumulation of organic matter on the bed of the body of water results in mobilisation of phosphate and subsequently in eutrophication, which can also result in sulphide being released. Sulphide is toxic and it therefore degrades the quality of the water, which has a negative impact on the biocoenoses in the water.

On land, Crassula helmsii's competition with other plants can cause shifts in the composition of species of bank vegetation on the banks of waters and humid dune slacks with low buffering capacity. These effects have been deemed irreversible as substantial and extremely costly measures are required in order to eradicate the species fully from ecosystems. There is very little quantitative information on this matter in the scientific literature and the evaluation of the effects are heavily reliant on the opinions of experts. For this reason, these aspects have been evaluated as having a moderate level of certainty.

Plant cultivation
The effect of Crassula helmsii on plant cultivation has been evaluated as low with high certainty. No indication has been found to show that Crassula helmsii affects cultivated plants by means of competition, hybridisation or the transfer of parasites/pathogens.

Domestic animals
The likelihood of the health of livestock animals being affected by plant substances, parasites or pathogens derived from Crassula helmsii has been evaluated as low with high certainty.

Public health
No indication has been found of any impact on public health stemming from contact with plants/plant substances or the transfer of parasites or pathogens. The likelihood of Crassula helmsii impacting public health has been evaluated as low with high certainty.

Other effects
This category includes effects on infrastructure, such as buildings, roads, dikes and hydrological engineering structures. High densities of Crassula helmsii can reduce drainage and cause hydrological engineering structures such as culverts to become blocked. The likelihood of such effects is high, although the damage is reversible. As a result, the risk has been classified as moderate. As quantitative information about the scale of the damage to infrastructure is lacking, the certainty of this risk classification has been evaluated as moderate.

Ecosystem services
Proliferation of Crassula helmsii in water catchment areas (such as dunes) can have slightly negative effects on water catchment due to increased evaporation levels. In addition, indirect effects on multifunctional ecosystems can also negatively impact production services for other species (such as the production of fish or the fulfilment of recreational functions). The species is cultivated for use in

aquariums and ponds, for which purpose it would be possible to make use of wild populations. The harvesting and sale of wild plants is considered a positive effect of the species on ecosystem production services. The balance of the positive and negative effects on all production services has been evaluated as neutral.

Local obstruction of drainage caused by Crassula helmsii is considered to have a negative effect on regulatory services for ecosystems. Due to its high biomass production, this species has a positive effect on carbon fixation and nutrient retention. Crassula helmsii is a hyperaccumulator of copper (it stores large quantities of this metal in its leaves) when high concentrations of this metal are present in the soil. It is likely that the plant will also be effective in extracting other elements from the water, as has been indicated by lower concentrations of silicon, zinc and aluminium in areas with a high biomass of Crassula helmsii. It is possible that this species could be used to clean up ecosystems contaminated by the bioaccumulation of metals such as copper, zinc and aluminium. However, no literature on this factor has been found. The effect on regulatory services has been evaluated as moderately negative.

Furthermore, due to the thick density and displacement of native species, the amenity value of ecosystems is reduced. The effect of this factor on cultural services has been assessed as moderately negative.

Estimate of costs and benefits

Impact on biodiversity and ecosystem services
Crassula helmsii can have a substantial impact on the biotic and abiotic environment and due to increasing spread of the species, these effects are also increasing. In part, these effects can also be produced by native species in certain environments, although in general, these native species are easier to control via adjusted control measures. No publications have been found that express the damage to biodiversity in financial terms.

The total costs stemming from impact on ecosystem services are unknown.

Impact on health, safety and the economy
Crassula helmsii can affect safety, water infrastructure and amenity value of nature conservation areas. Costs are incurred when recreational activities are impaired or cancelled. In practice, plenty of alternative locations for recreation are available, although this could change if Crassula helmsii was to propagate further.

Drainage from canals and hydraulic engineering structures must be guaranteed and removal of the plant from these locations costs money. No report of these costs is available. The same applies for losses incurred as a result of degradation of the aesthetic value of nature conservation areas.

Costs of control measures
Combating a species is extremely difficult when even the smallest stem fragment can develop into a fully grown plant. In order to be effective, the measures must be extremely thorough and years of aftercare will be required to truly eradicate the species. It is especially difficult to eliminate the plant as many of the control measures result in ideal conditions for regrowth or new establishment of the plant. Eradication is only possible if the location can be drained. If drainage is not

possible, then the only remaining options are to control the growth or to do nothing at all. In newly isolated areas of growth, the population size is still low and the likelihood of re-establishment is lower, which means the probability of small-scale control measures resulting in successful eradication is higher.

Any measures to combat Crassula helmsii must always be tailor-made. When selecting the most suitable measures, you must examine the characteristics of the infestation, the infected location, and in some cases, the surrounding area.

The cost of eradicating and/or controlling Crassula helmsii are very high. In the UK, the cost of controlling 600 locations over a period of 2-3 years has been estimated at between £2-3 million (Leach & Dawson, 1999). (Kelly & Maguire, 2009) The cost of cleaning up a small garden pond is estimated to be £500, which can increase to £5,000 for larger ponds and small river systems. Furthermore, they indicate that effort and funding must continue until the species has been fully eradicated. The cost of cleaning up a lake, canal or larger river system can reach between £50,000 and £110,000 in the first year alone.

In Ireland, the total cost of controlling, researching and restoring treated areas in the period up to 2012 was estimated at €350,000. The largest proportion of these costs resulted from having to implement control measures in a single waterway twice. In 2013, a total investment of €1,533,466 was spent on a project to fully eradicate Crassula helmsii from three different locations.

In the Netherlands, more than €6 million has been spent on research, eradication and control of Crassula helmsii from 2017 onwards. The minister's answers to various questions from the Dutch House of Representatives included a figure of €10 million, of which over €4 million was spent in 2018 and 2019 by the provinces of Friesland, Drenthe, Gelderland, Utrecht, Noord-Holland, Noord-Brabant and Limburg for the purposes of control measures. These measures focused on a limited amount of area with relatively high costs in each area. Terschelling is an outlier, with the province of Friesland contributing €3,370,000 to a €5 million project (Tweede Kamer, 2020). The highest proportion of these costs stemmed from research into the characteristics of the species' establishment areas and ecology and to find cost-effective control measures such as the development of systematic management.
Costs were also incurred as a result of measures to mitigate the risk of flooding, although the total cost of these measures is unknown.

Revenue
Crassula helmsii is a potential source of nectar for insects, although the value of this regulatory service is unknown.

Crassula helmsii is sold as an oxygenating plant for aquariums and ponds, so the species contributes to product-provision services. We do not have any data on the benefits of Crassula helmsii, although the plant is sold in a few places in the Netherlands, often under the name 'naaldkruid' (Crassula recurva). The now-defunct Netherlands Aquatic Plants Agreement (2010) included Crassula helmsii in Annex 1, meaning that the plant was no longer sold to consumers by the partners

participating in the agreement.[6] The total economic value of the plant is estimated to be low and plenty of alternative oxygenating plants are available.

Due to its high biomass production, this species has a positive effect on carbon fixation and nutrient retention.

Crassula helmsii is a hypoaccumulator of copper (it stores large quantities of this metal in its leaves) when high concentrations of this metal are present. It is likely that the plant will also be effective in extracting other elements from the water, as has been indicated by lower concentrations of silicon, zinc and aluminium in areas with a high biomass of Crassula helmsii. It is possible that this species could be used to clean up ecosystems contaminated by the bioaccumulation of metals such as copper, zinc and aluminium. However, no literature on this factor has been found.

Conclusions
Crassula helmsii has a negative impact on biodiversity and ecosystems. The species is being combated in a large number of places at significant cost. To a small extent, Crassula helmsii is sold as an oxygenating plant for aquariums and ponds, which can contribute to further spread of the species. There are no indications that the commercial value of Crassula helmsii is high and it is suspected to be minimal compared to the impact on biodiversity and ecosystem as well as the cost of control measures.

[6] https://zoek.officielebekendmakingen.nl/stcrt-2010-11341.html#d8401e497

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