Australian Swamp Stonecrop (*Crassula helmsii*)

A Technical Review of Distribution, Ecology, Impacts, and Management

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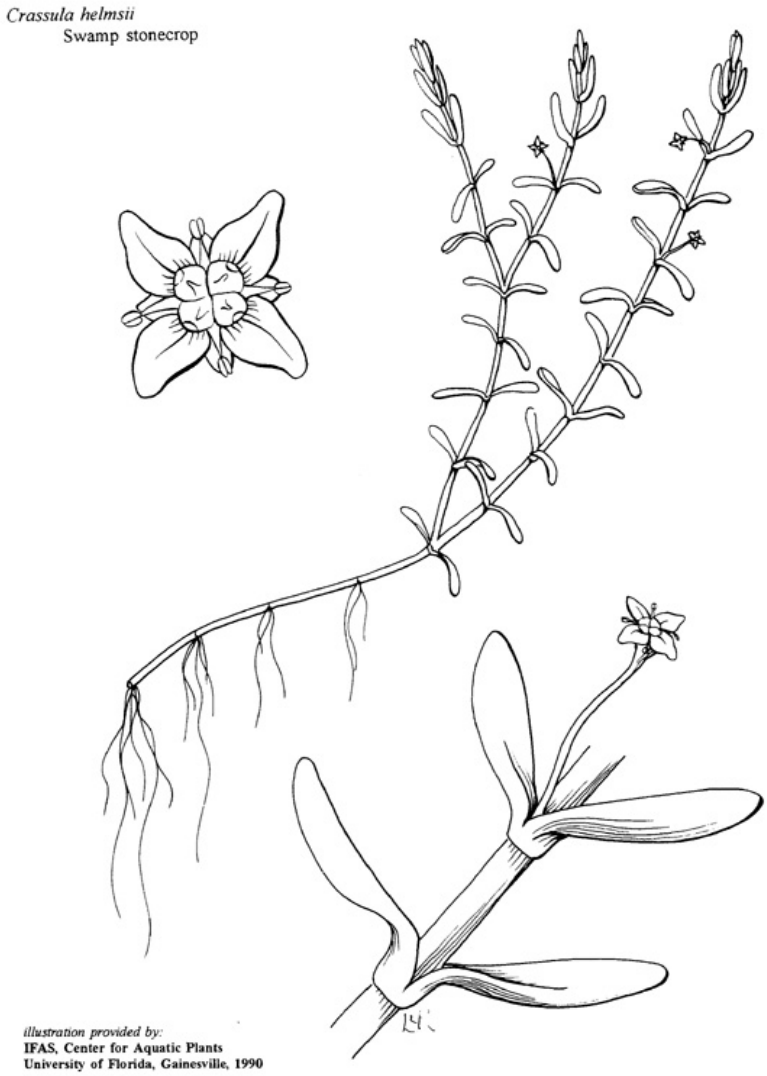

Crassula helmsii

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Australian Swamp Stonecrop, (*Crassula helmsii*): A Technical Review of Distribution, Ecology, Impacts, and Management

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This literature review was commissioned by the nonprofit Centre for Agricultural Bioscience International (CAB International; http://www.cabi.org/index.asp) as part of a larger invasive species compendium. We completed eight literature reviews for the initial project, which we have made available as DNR miscellaneous publications. Species included in the initial review include:

Carolina fanwort (*Cabomba caroliniana*) – [PUB-SS-1047 2009]
European frog-bit (*Hydrocharis morsus-ranae*) – [PUB-SS-1048 2009]
Indian swampweed (*Hygrophila polysperma*) – [PUB-SS-1049 2009]
African elodea (*Lagarosiphon major*) – [PUB-SS-1050 2009]
Yellow floating heart (*Nymphoides peltata*) – [PUB-SS-1051 2009]
Curly leaf pondweed (*Potamogeton crispus*) – [PUB-SS-1052 2009]
Water spangles (*Salvinia minima*) – [PUB-SS-1053 2009]
Water chestnut (*Trapa natans*) – [PUB-SS-1054 2009]

This review was completed for CAB International after the reviews listed above, and maintains the same format.

In completing the literature reviews, we preferentially consulted the peer-reviewed primary literature and supplemented the reviews with secondary sources where necessary. The outline for the reviews is identical for each species and was provided as part of the CAB International commissioning. This effort compliments work conducted during the development of the WDNR's proposed invasive species identification, classification and control rule; a more exhaustive list of species and accompanying literature review summaries can be found on the DNR website at: http://dnr.wi.gov/invasives/

Identity

Taxonomy and Nomenclature

The genus *Crassula* (family Crassulaceae) contains approximately 200-300 species, of which only a few species are adapted to wet conditions, and 23 are considered weeds (Sheppard et al., 2006; Winterton and Scher, 2007). The genus name *Crassula* is the diminutive of the Latin 'crassus' which means 'thick' or 'fat', referring to the fleshy, succulent nature of the genus as a whole. The genus is found almost worldwide, although the majority of species are from the southern parts of Africa. *Crassula helmsii* was originally classified as *Bulliarda recurva* Hook.f. in 1847, and revised to *Tillaea recurva* (Hook.f.) Hook.f. in 1857. *Crassula recurva* (Hook.f.) Ostenf. and *Crassula recurva* N.E.Br. were both also suggested as proper nomenclature. The taxonomy was further revised to *Tillaea helmsii* Kirk in 1899, and ultimately revised to *Crassula helmsii.* There are varying reports of authority, with both *Crassula helmsii* (Kirk) Cockayne, 1907, and *Crassula helmsii* A. Berger, 1930 reported in the literature (IPNI, 2008; USDA-NRCS, 2006; USDA-GRIN, 2002). Many of the unaccepted scientific names of *C. helmsii* are still often used when this plant is dealt with in the aquarium trade (OEPP/EPPO, 2007; CAPM-

CEH, 2004). As the English common names suggest, *C. helmsii* originates from Australia and New Zealand.

Summary of Invasiveness

C. helmsii is an aquatic plant that can take on various growth forms depending on prevailing conditions, and is able to act as a submerged, emergent, or semi-terrestrial species. *C. helmsii* has the ability to form dense stands of 100% cover, which cause many negative environmental and economic impacts including displacing native plant species, reducing biodiversity, decreasing water quality and flow, impeding recreational activities, and diminishing aesthetic value. *C. helmsii* is extremely difficult and costly to control, and its ability to form new plants vegetatively facilitates its spread to new locations. The trade and potential escape of *C. helmsii* through the aquarium and water garden industry may play a large role in its spread to new locations. In addition, the transportation of this plant on recreational equipment or by wildlife moving between water bodies may also play a role in its localized spread. *C. helmsii* is native to Australia and New Zealand, and has established as an exotic invasive in many parts of Europe, especially the United Kingdom. *C. helmsii* is declared a noxious weed in Florida and North Carolina, and some sources report *C. helmsii* as occurring in these states (OEPP/EPPO, 2004; OEPP/EPPO, 2006), but the status of these populations is unknown. *C. helmsii* is also declared a noxious weed in New Hampshire and Washington (USDA-GRIN, 2002), and is considered a prohibited species in Minnesota (MDNR, 2006) and Wisconsin (WDNR, 2009), though it is not known to occur in these states.

Distribution, Introduction, and Spread

Distribution

C. helmsii is native to New Zealand and Australia, including the territories of New South Wales, South Australia, Tasmania, Victoria, and Western Australia (OEPP/EPPO, 2007). In New Zealand, it is reported as being naturally uncommon, and is known only from the West Coast of the South Island from Karamea south to Haast (NZPCN, 2005).

C. helmsii is currently naturalized in several areas of Europe, including the United Kingdom, Germany, Belgium, Ireland, Netherlands, Denmark, France, Spain, Italy, Austria, and the Baikal Region of Russia (OEPP/EPPO, 2004; NOBANIS, 2005; OEPP/EPPO, 2007; Afferni and Tavormina, 2007; Minchin, 2008). *C. helmsii* has been reported as being present in Portugal (OEPP/EPPO, 2004), but its presence has since been invalidated (OEPP/EPPO, 2007). There are reports of *C. helmsii* occurring in Florida and North Carolina in the Southeastern United States (OEPP/EPPO, 2004; OEPP/EPPO, 2006; Minchin, 2008), but the extent of distribution and current status of these populations is unknown.

History of Introduction and Spread

C. helmsii was introduced from Tasmania to England in 1911, and sold throughout the 1920s as an 'oxygenating plant' in the aquarium trade (CAPM-CEH, 2004). The first population reported in the wild was in 1956, in Greensted Pond, Essex (OEPP/EPPO, 2007). Until the 1970s, *C. helmsii* was commercially available only through one supplier, Perry's Hardy Plant Farm in Enfield, Middlesex, though it is now readily available through multiple suppliers (Dawson and Warman, 1987; Leach and Dawson, 1999). Since the initial introduction of *C. helmsii* to the United Kingdom, the number of sites invaded by the plant has doubled every 2 years, with over 1500 sites reported in the British Isles, though this is probably an underestimate of its true distribution (Environment Agency, 2003; OEPP/EPPO, 2007).

C. helmsii was first recorded in Germany in 1981, and has spread to many parts of the country including Hamburg, Hanover, Schleswig and the Pfalzerwald and Westphalia areas (Leach and Dawson, 1999). *C. helmsii* was first recorded in Belgium in 1982, and is described as being locally present (NOBAINS, 2005; OEPP/EPPO, 2007). *C. helmsii* was first reported in Northern Ireland in 1984 in a pool at Gosford (OEPP/EPPO, 2007). In Ireland, *C. helmsii* has a relatively restricted distribution compared to that of England and Wales (Kelly and Maguire, 2009). *C. helmsii* was first found in the Netherlands in 1995 in a nature reserve near Breda, and has also established localized populations in ponds in the provinces of Noord-Brabant and Zeeland (OEPP/EPPO, 2007). *C. helmsii* was first reported in Denmark in 2003, and its frequency of invaded sites is reported as low (NOBANIS, 2005).

C. helmsii has been recorded in Spain, but so far its presence has not been reported as invasive (OEPP/EPPO, 2004). Reports of *C. helmsii* occurring in Portugal have been invalidated (OEPP/EPPO, 2007). Localized populations of *C. helmsii* have been reported growing in several ponds in the Trieste district of Italy (Afferni and Tavormina, 2007). *C. helmsii* has also been reported as being present in France (OEPP/EPPO, 2004) and Austria (Minchin, 2008). *C. helmsii* has been recorded as a rare plant found in the Baikal Region of Russia (Asovsky, 1981; OEPP/EPPO, 2004).
OEPP/EPPO, 2004 and OEPP/EPPO, 2006 report *C. helmsii* as occurring in Florida and North Carolina, but the pathway of introduction and current status of these populations is unknown.

Risk of Introduction
C. helmsii is continuing to expand its range and become more abundant (Minchin, 2008). *C. helmsii* is a very popular aquarium and water garden plant, and the increased availability to order this plant over the internet and through mail order gives it the ability to travel to all parts of the world. In addition, *C. helmsii* is often found as a 'contaminant' or 'hitchhiker' plant with other species ordered through water garden catalogs (Environment Agency, 2003). *C. helmsii* has escaped confinement and has been intentionally or accidentally introduced on several occasions outside of its native range. *C. helmsii* is a highly competitive plant which is capable of rapid growth and spread. In the locales to which it has been introduced, it has often become the dominant plant species, outcompeting natives and displacing other species which depend on the ecosystem.

Biology and Ecology

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

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

Similarities to Other Species
C. helmsii is closely related to *Crassula aquatica,* though the two species can be distinguished based upon the size and position of their flowers (OEPP/EPPO, 2007). *Crassula campestris,* a South African species, is naturalized in Spain (Sheppard et al., 2006). The submerged stems of *Callitriche* species may also be mistaken for *C. helmsii,* but *Callitriche* species are never emergent, and also have a distinct notch at the leaf tips (Environment Agency, 2003; OEPP/EPPO, 2007). The genus *Crassula* may also be confused with the genus *Microcarpaea* (Winterton and Scher, 2007).

Habitat
C. helmsii can grow in several different growth forms, establishing in submersed waters up to 3m (10 ft) deep, and also as an emergent or semi-terrestrial plant on damp ground (Sheppard et al., 2006). The morphology of the plant changes between these different growth forms according to the prevailing environmental conditions (OEPP/EPPO, 2007), although the submersed form of the plant is not known in its native range (Sheppard et al., 2006). *C. helmsii* inhabits lakes, ponds, gravel pits, inland and coastal wetlands, marshes, swamps, rivers, canals, and irrigation ditches.

Genetics
C. helmsii has a reported chromosome number of 2n=36 (Stace et al., 2005; Lockton, 2009). Studies of genetic variation shows that it is likely that only one introduction of *C. helmsii* was made into Britain, with the likely source population being the plants growing along the River Murray in Australia (OEPP/EPPO, 2007).

Genetic studies of New Zealand plants show a difference in chromosome number, with Australian plants being diploid (2n=14), and the smaller, more delicate plants from New Zealand being hexaploid (2n=42) (NZPCN, 2005).

Reproductive biology
C. helmsii has the ability to prolifically reproduce vegetatively through fragments, with fragments as small as a single node on a 5mm stem being capable of producing a new plant (CAPM-CEH, 2004). In addition, apical turions are produced in the autumn (in the United Kingdom), which then float along the waters' surface (OEPP/EPPO, 2007). *C. helmsii* also can reproduce sexually, though production of viable seeds is uncertain in Europe (OEPP/EPPO, 2007).

Physiology and Phenology
In its native range, *C. helmsii* flowers in November and December, with flowering continuing to February in New Zealand (OEPP/EPPO, 2007). In Europe, flowers appear between July and September, though the viability of seeds in Europe is uncertain (OEPP/EPPO, 2007). *C. helmsii* is able to grow throughout the year without a dormant period (CAPM-CEH, 2004).

Environmental Requirements
C. hemsii can colonize a variety of waters, from static systems to gradually-flowing systems, and is able to withstand periods of extended drying. It colonizes waters ranging from acid to alkaline, and has also been recorded in semi-saline water bodies (OEPP/EPPO, 2007). *C. helmsii* is associated with soft sediments and possibly also with iron-rich waters (Dawson and Warman, 1987). In its native range, *C. helmsii* appears to be confined to areas where summer temperatures are 20-25°C with 100-550 mm precipitation, and winter temperatures are 0-15°C

with 200-3000 mm precipitation, including extended periods under snow (Leach and Dawson, 1999; OEPP/EPPO, 2007). *C. helmsii* can survive a wide range of climatic variation, from averages of 30°C in the summer to less than -6°C in winter (OEPP/EPPO, 2007). It is a lowland plant, occurring in altitudes from sea level up to 345m (Lockton, 2009).

Movement and dispersal

Natural dispersal
Hydrochory, the dispersal of disseminules by water currents, seems to be the main dispersal mode of vegetative fragments within a watershed.

Vector Transmission
C. helmsii can be transported with birds, wildlife, or mud and carried to new locations (OEPP/EPPO, 2007; Minchin, 2008). The spread of the plant by livestock may be a significant contributor to its continued spread (Wicks, 2004).

Accidental Introduction
C. helmsii is often found as a 'contaminant' or 'hitchhiker' plant with other species ordered through water garden catalogs (Environment Agency, 2003). *C. helmsii* has been introduced through hobbyists emptying unwanted aquarium species directly into surrounding waterways, and can also be accidentally introduced by water garden ponds flooding into surrounding natural waterways. Due to the ability of *C. helmsii* to reproduce via small fragments, plants could also be spread accidentally to new locations by the movement of boats, trailers, nets, anglers, and other recreational equipment between water bodies.

Intentional Introduction
The trade of this plant as a submerged 'oxygenating' aquarium plant through the internet and mail order has greatly increased its availability and ease of spread into new environments.

Natural Enemies
Few natural enemies of *C. helmsii* are reported in the literature, and the plant is known to occasionally be a nuisance in its native range (Sheppard et al., 2006).

Impacts

Economic Impact
C. helmsii has limited water flow in irrigation channels and flood-control systems (Kelly and Maguire, 2009). In addition, the loss of recreational and aesthetic value associated with *C. helmsii* can also cause a decline in waterfront property values, as well as possible declines in tourism related revenue for the community. One recent estimate puts control costs of *C. helmsii* to be between 1.45-3 million euros ($2.1-4.4 million US dollars) to control 500 sites over 2-3 years (Leach and Dawson, 1999).

Social Impact
C. helmsii can form dense mats that impede recreational activities such as boating, fishing, swimming, water skiing, canoeing, and kayaking. In addition, unsightly mats of vegetation decrease aesthetic values, and can be mistaken as dry land with associated dangers for animals and humans (Sheppard et al., 2006).

Impact on Habitat

The dense stands and mats of vegetation that are characteristic of this species when introduced outside of its native range can decrease the oxygen levels by limiting water circulation and increased decomposition of dead plants. Dense mats of *C. helmsii* also have the ability to change water hydrology and quality, negatively affecting the ecosystem in which it occurs. The plant is able to grow throughout the year without a dormant period, allowing it to occupy its niche throughout the entire year (CAPM-CEH, 2004). The very rapid growth of *C. helmsii* also allows it to uptake almost all the available nutrients (Environment Agency, 2003). The submerged form of *C. helmsii* is uniquely adapted to assimilate CO_2 for 20 hours of the day due to the plants' possession of crassulacean acid metabolism (CAM) (Keeley, 1998).

Impact on Biodiversity
C. helmsii is winter hardy and has the ability to form 100% cover, giving it the ability to outcompete and displace native plant species which typically dieback in the winter (OEPP/EPPO, 2007; Hackney, 2009). A thin covering of *C. helmsii* can cause significant germination suppression in some plant species (Langdon et al., 2004). Dense mats suppress native flora and create a poor ecosystem for invertebrates, amphibians, and fish (CAPM-CEH, 2004; Minchin, 2008). Decomposing mats of *C. helmsii* also have the ability to cause fish kills by creating severe fluctuations in dissolved oxygen levels in the water (OEPP/EPPO, 2007).

Several rare or threatened species in the United Kingdom may also be negatively impacted by the spread of *C. helmsii* (OEPP/EPPO, 2007). Reduced breeding success of a protected species of great crested newt (*Triturus cristatus*), has been attributed to invasion of ponds by *C. helmsii* (Langdon et al., 2006). The rare starfruit plant, *Damasonium alsima,* is thought to be threatened by *C. helmsii* (Watson, 2001). *C. helmsii* may smother *Callitriche* spp., and outcompete charophytes (stoneworts) for space (Hackney, 2009). In addition, a study in England shows a significant reduction in the diatom *Synedra delicatissima*, caused by the introduction of *C. helmsii* (Hackney, 2009).

Management

Economic Value
C. helmsii is sold in garden centers and nurseries as a submerged oxygenating plant for aquariums and water ponds (OEPP/EPPO, 2007). Overall, its value in minor, and other noninvasive aquarium and pond species are available.

Environmental Services
In Europe, *C. helmsii* flowers late into the winter and may provide a useful source of nectar (Lockton, 2009).

Invasive Species Management

Prevention
As with all invasive species management, prevention is better and more cost-effective than control.

Detection and Inspection Methods
Infestations of aquatic invasive species are often first reported at boat launches and public access points, and these areas should be monitored frequently in order to eradicate or control new invasions at an early stage. Users should inspect all recreational equipment before leaving any water body, and any visible plants, animals, or sediment should be removed. In addi-

tion, rinsing gear with hot water or steam may help in removing any additional non-visible organisms.

Rapid Response
Early detection and treatment is essential in the prevention of future invasions and spread of *C. helmsii*. Smaller, localized populations have better success at being controlled than those which have the opportunity to spread and become well-established (Environment Agency, 2003).

Public Awareness
Several publications have been produced in areas with *C. helmsii* populations regarding the impacts of invasive species and the steps that aquarists and lake recreationists need to take in order to prevent introducing and spreading aquatic invasives.

Cultural Control and Sanitary Measures
In several regions where aquatic invasives have established, governmental organizations have started requiring that recreationists drain all water and clean off all gear (boats, trailers, fishing equipment, nets, etc.) used on water bodies in order to minimize the chance of spreading aquatic invasive species, such as *C. helmsii*, to other areas.

Physical and Mechanical Control
Control of *C. helmsii* has had limited efficacy due to its ability to propagate vegetatively through small fragments. Attempts to mechanically harvest only serve as means of creating and introducing more plant fragments, potentially aiding in dispersal to new locations (CAPM-CEH, 2004). *C. helmsii* is also tolerant of shade, extreme cold, and desiccation, making it very difficult to control. Small patches may be able to be controlled with plastic shade material, but the material must remain in place for 8 weeks up towards 6 months (CAPM-CEH, 2004), and the process is very labor intensive and causes much disturbance (Bridge, 2005). Freezing with liquid nitrogen has been effective on small populations, and surrounding medium sized populations with a fine wire mesh fence can aid in targeted removal and preventing further spread (OEPP/EPPO, 2007). Dredging of near shore or emergent vegetation throughout the year can also be an effective control. It is recommended that all dead plant material be removed to reduce potential oxygen depletion through decomposition.

Movement Control
Several countries have banned the importation or sale of exotic plants, such as *C. helmsii*, in attempts to minimize the chance of introduction to non-native regions.

Biological control
There are no known biological control agents for *C. helmsii* and more information on the plant in its native range needs to be collected (Gassmann et al., 2006). Grass carp will feed to a limited extent on small populations of *C. helmsii,* but the plant is not its preferred food (Dawson and Warman, 1987). Introduction of grass carp can negatively impact the coexisting native submerged vegetation, and introduction is even prohibited in some countries.

Chemical Control
C. helmsii is susceptible to chemicals containing diquat and glyphosate (Dawson, 1996; CAPM-CEH, 2004). Diquat is best applied in the autumn or winter, and water temperatures should be >12ºC (Minchin, 2008). In the European Union where diquat is banned in aquatic use, early spring application of dichlobenil is often used when the plant is still entirely submerged (CAPM-

CEH, 2004). Glyphosate should be applied from April to late November, when the majority of the plant is emergent. It is recommended that at least 70% of dense populations be chemically treated at one time to reduce potential re-colonization from untreated areas, and the remaining 30% should be treated one week later (CAPM-CEH, 2004). In an English nature preserve, a hot biodegradable foam made of coconut and corn sugars was reported as being able to control approximately 50% of the population, but did not eradicate it (Bridge, 2005). Hydrogen peroxide has been experimented with as a potential control method, but only plant scorching and temporary suppression of plant material was achieved (Dawson and Henville, 1991).

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Crassula helmsii
Succulent leaves, pedicellate flowers

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