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Weed Risk Assessment for *Crassula helmsii* (Kirk) Cockayne (Crassulaceae) – Swamp stonecrop

Left: *Crassula helmsii* flowers (source: The Wild Flower Society, 2013). Right: *Crassula helmsii* infestation (source: Waterland Management Ltd., 2013).

Agency Contact:

Plant Epidemiology and Risk Analysis Laboratory
Center for Plant Health Science and Technology

Plant Protection and Quarantine
Animal and Plant Health Inspection Service
United States Department of Agriculture
1730 Varsity Drive, Suite 300
Raleigh, NC 27606

Introduction Plant Protection and Quarantine (PPQ) regulates noxious weeds under the authority of the Plant Protection Act (7 U.S.C. § 7701-7786, 2000) and the Federal Seed Act (7 U.S.C. § 1581-1610, 1939). A noxious weed is defined as "any plant or plant product that can directly or indirectly injure or cause damage to crops (including nursery stock or plant products), livestock, poultry, or other interests of agriculture, irrigation, navigation, the natural resources of the United States, the public health, or the environment" (7 U.S.C. § 7701-7786, 2000). We use weed risk assessment (WRA)—specifically, the PPQ WRA model (Koop et al., 2012)—to evaluate the risk potential of plants, including those newly detected in the United States, those proposed for import, and those emerging as weeds elsewhere in the world.

Because the PPQ WRA model is geographically and climatically neutral, it can be used to evaluate the baseline invasive/weed potential of any plant species for the entire United States or for any area within it. As part of this analysis, we use a stochastic simulation to evaluate how much the uncertainty associated with the analysis affects the model outcomes. We also use GIS overlays to evaluate those areas of the United States that may be suitable for the establishment of the plant. For more information on the PPQ WRA process, please refer to the document, *Background information on the PPQ Weed Risk Assessment*, which is available upon request.

***Crassula helmsii* – Swamp stonecrop**

Species Information

Family: Crassulaceae

Synonyms: *Crassula recurva* (Hook. f.) Ostenf. (Laundon, 1961) and *Tillaea recurva* (Hook f.) (Dawson, 1994).

Initiation: PPQ initiated this weed risk assessment after the United Kingdom prohibited the sale of *Crassula helmsii* and four other aquatic plants. This is the first time the United Kingdom has enacted this type of ban (Kinver, 2013).

Foreign distribution: *Crassula helmsii* is native to Australia and New Zealand, and has been introduced to and become naturalized in the United Kingdom (NGRP, 2013), Ireland (Reynolds, 2002), Spain (Dana, 2002), France (Brunel et al., 2010), Belgium (Dawson and Warman, 1987), Denmark (OEPP/EPPO, 2007), Germany (Dawson, 1994), and the Netherlands (Brouwer and den Hartog, 1996).

U.S. distribution and status: *Crassula helmsii* does not occur in the United States outside of cultivation (Kartesz, 2013; ODA, 2007). Reports of *C. helmsii* naturalized in the United States (ISSG, 2013) are erroneous: they mistake the states that *regulate* this plant for occurrence of it. *Crassula helmsii* is regulated as a noxious weed by Florida, Indiana, Minnesota, North Carolina, and Washington (NGRP, 2013). Additionally, the Ornamental Aquatic Trade Association (OATA) has advised its members to stop selling *C. helmsii* and avoid recklessly disposing plants (Appleby, 2010; Friday, 2013; OEPP/EPPO, 2007). *Crassula helmsii* is available for sale online as an aquarium plant (Java Aquatic Plants, 2013) but we found no evidence in numerous botanical and garden databases that this plant is cultivated or commercially traded in the United States. Therefore, we believe that this plant is perhaps only cultivated at a very minor scale in the United States, if at all, and may only be traded and propagated by hobbyists.

WRA area[1]: Entire United States, including territories.

1. *Crassula helmsii* analysis

Establishment/Spread Potential *Crassula helmsii* is an aquatic plant that has spread rapidly in the United Kingdom (Dawson and Warman, 1987; OEPP/EPPO, 2007). It was first detected in a pond in Great Britain in 1956, and by 1994 had spread to 390 sites across Great Britain. Isoenzyme analysis has indicated that all of these populations likely came from a single introduction into Great Britain (Dawson, 1994). *Crassula helmsii* is shade tolerant (Dawson and Warman, 1987; The National Trust Conservation Newsletter, 2004), forms dense mats in aquatic vegetation (Dawson and Warman, 1987), and produces vegetative propagules that are dispersed by water, on animals, and unintentionally by humans during activities such as fishing, hiking, and restocking ponds (Dawson and Warman, 1987; Dawson, 1994). We had a slightly greater than average amount of uncertainty for this risk element.

Risk score = 21 Uncertainty index = 0.21

Impact Potential *Crassula helmsii* smothers native vegetation (Dawson and Warman, 1987) and outcompetes native plants because it does not go dormant (OEPP/EPPO, 2007). Unusual for an aquatic plant, it also utilizes Crassulacean acid metabolism (CAM) which enables it to take up carbon dioxide at night (ISSG, 2013). In the United Kingdom, *C. helmsii* threatens protected plant species and reduces the breeding success of protected newts (CEH, 2004; OEPP/EPPO, 2007; Langdon et al., 2004). Additionally, dense infestations of *C. helmsii* can deplete the oxygen content of water, causing declines in fish, frog, and invertebrate populations (CEH, 2004; Minchin, 2008; Stokes et al., 2004). This plant also blocks drainage channels, can cause flooding (OEPP/EPPO, 2007), and impacts fisheries (Dawson, 1989). Because of these impacts, *C. helmsii* is controlled in waterways in natural areas and urban and suburban settings in Europe (Dawson and Warman, 1987; Spencer-Jones, 1994; The National Trust Conservation Newsletter, 2004). We had a low amount of uncertainty for this risk element.

Risk score = 3.9 Uncertainty index = 0.14

[1] "WRA area" is the area in relation to which the weed risk assessment is conducted [definition modified from that for "PRA area" (IPPC, 2012).

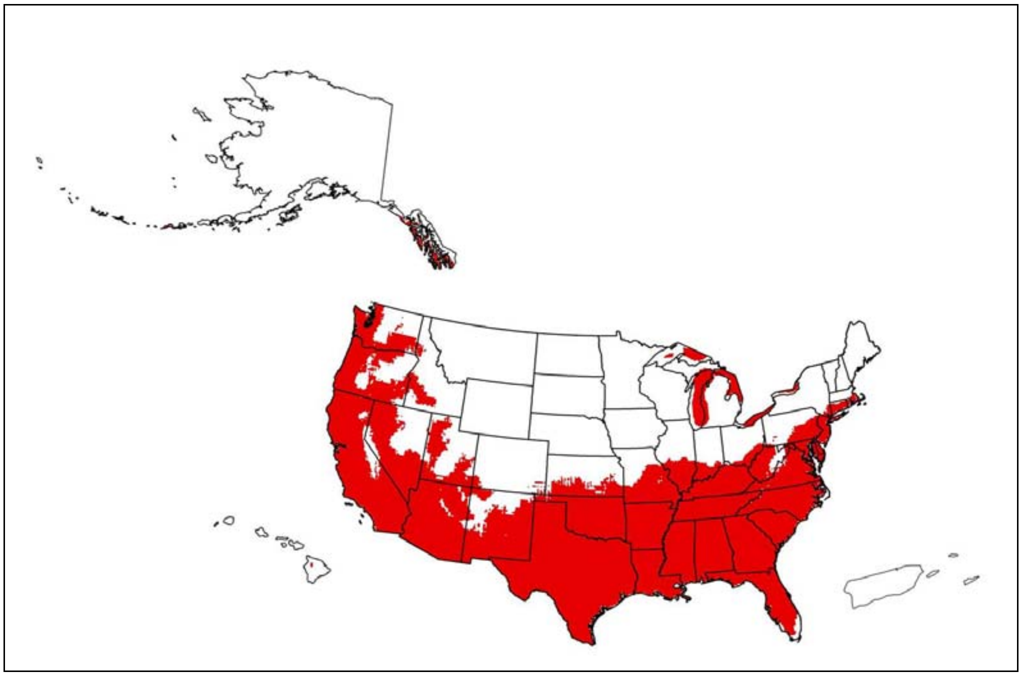
Geographic Potential Based on three climatic variables, we estimate that about 45 percent of the United States is suitable for the establishment of *C. helmsii* (Fig. 1). This predicted distribution is based on the species' known distribution elsewhere in the world and includes point-referenced localities and areas of occurrence. The map for *C. helmsii* represents the joint distribution of Plant Hardiness Zones 7-11, areas with 0-100+ inches of annual precipitation, and the following Köppen-Geiger climate classes: steppe, desert, Mediterranean, humid subtropical, marine west coast, humid continental warm summers, and humid continental cool summers. Note that it was not clear whether *C. helmsii* occurs in the humid continental warm summers climate zone; here we assumed that environment was suitable for it. *Crassula helmsii* can grow in mud, partly emerged in shallow water, or fully submerged as deep as 3 meters underwater (Dawson and Warman, 1987; Laundon, 1961). It grows in both still and flowing water (Dawson, 1994). It is interesting to note that the Great Lakes, which moderate the local climate (Scott and Huff, 1997), are also included in the predicted distribution for *C. helmsii*.

The area estimated likely represents a conservative estimate as it only uses three climatic variables. Other environmental variables, such as soil and habitat type, may further limit the areas in which this species is likely to establish.

Entry Potential *Crassula helmsii* is grown as an aquarium plant and is available for sale online (Java Aquatic Plants, 2013). *Crassula helmsii* can contaminate other water plants being sold (OEPP/EPPO, 2007), is dispersed in water during stocking ponds with ornamental fish (Dawson and Warman, 1987), can be transported to new sites by boats (Dawson and Warman, 1987), and in mud (OEPP/EPPO, 2007).

Risk score = 0.6 Uncertainty index = 0.08

Figure 1. Predicted distribution of *Crassula helmsii* in the United States. Map insets for Alaska, Hawaii, and Puerto Rico are not to scale.



2. Results and Conclusion

Model Probabilities: P(Major Invader) = 95.9%
P(Minor Invader) = 3.9%
P(Non-Invader) = 0.1%

Risk Result = High Risk

Secondary Screening = Not Applicable

Figure 2. *Crassula helmsii* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

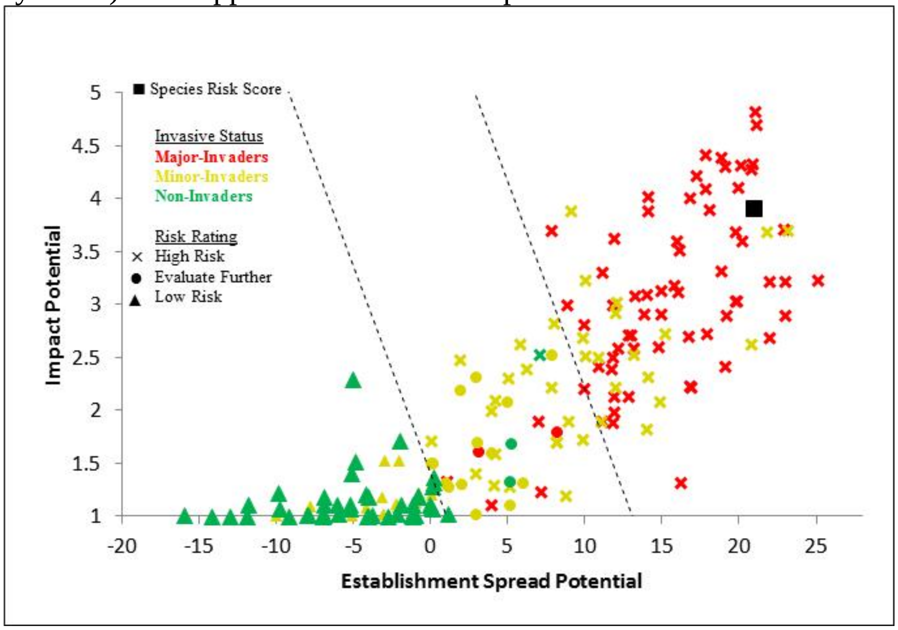
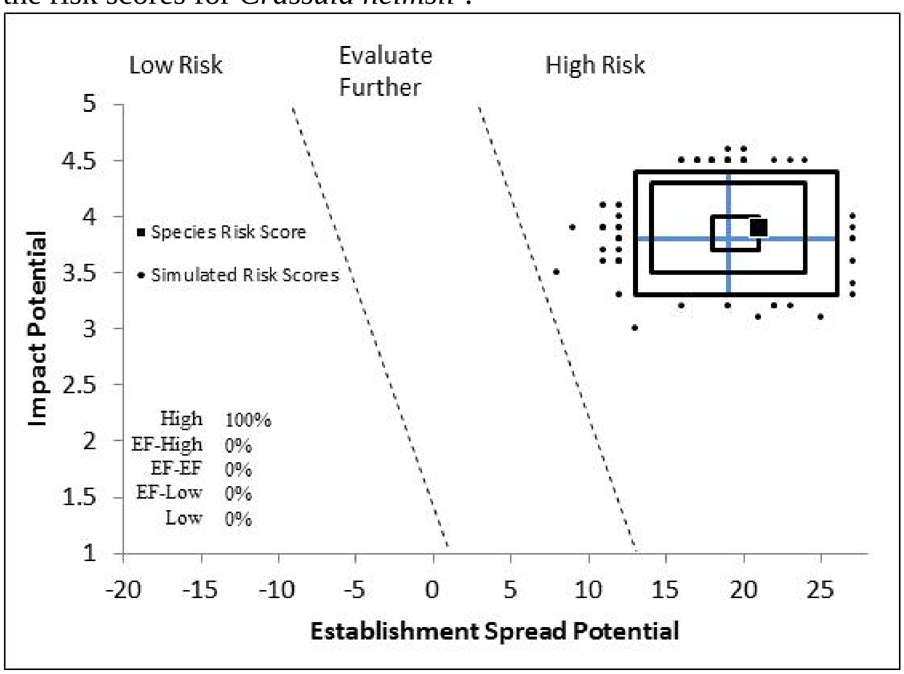


Figure 3. Monte Carlo simulation results (N=5,000) for uncertainty around the risk scores for *Crassula helmsii*[a].



[a] The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

3. Discussion

The result of the weed risk assessment for *Crassula helmsii* is High Risk. *Crassula helmsii* has a risk score similar to that of other high risk invaders (Fig. 2). Our conclusion is robust because all of the simulated risk scores generated by our uncertainty analysis resulted in conclusions of high risk as well (Fig. 3). *Crassula helmsii* has rapidly spread across water bodies in the United Kingdom, where it suppresses native plant species (Dawson and Warman, 1987) and depletes water of oxygen, resulting in fish, frog, and invertebrate population declines (Minchin, 2008; Stokes et al., 2004). Once established, *C. helmsii* can be difficult to eradicate, because mechanically removing the plant releases vegetative propagules that can re-infest the treated area or spread to new locations (CEH, 2004; Dawson and Warman, 1987). Additionally, if herbicide applications fail to kill the entire population of plants, the dying stems will release actively growing fragments that rapidly recolonize the area (Dawson, 1994). *Crassula helmsii* control costs over 2 to 3 years in the United Kingdom were estimated to be between 1.45 and 3 million EUR (OEPP/EPPO, 2007).

4. Literature Cited

7 U.S.C. § 1581-1610. 1939. The Federal Seed Act, Title 7 United States Code § 1581-1610.

7 U.S.C. § 7701-7786. 2000. Plant Protection Act, Title 7 United States Code § 7701-7786.

Angling Trust. 2009. Angling Trust News. Angling Trust, Herefordshire, United Kingdom. Last accessed September 26, 2013, http://anglingtrust.net/news.asp?section=29&from=2009/01/01&to=2010/01/01&page=6&itemid=218.

Appleby, M. 2010. Campaign targets 'reckless disposal' of invasive plants. Horticulture Week, London, United Kingdom. Last accessed September 26, 2013, http://www.hortweek.com/Landscape/article/986078/Campaign-targets-reckless-disposal-invasive-plants/.

Bailey, L. H., and E. Z. Bailey. 1976. Hortus Third: A Concise Dictionary of Plants Cultivated in the United States and Canada. Macmillan, London, United Kingdom. 1290 pp.

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

Brouwer, E., and C. den Hartog. 1996. *Crassula helmsii* (Kirk) Cockayne, an adventive species on temporarily exposed sandy banks. Gorteria 22(6):149-152.

Brunel, S. (ed.). 2005. Proceedings of the International Workshop on Invasive Plants in Mediterranean Type Regions of the World. Council of

Europe Publishing, Mèze, France. 285 pp.
Brunel, S., A. Uludag, E. Fernandez-Galiano, and G. Brundu (eds.). 2010. Proceedings of the 2nd International Workshop on Invasive Plants in the Mediterranean Type Regions of the World. Steering Committee, Trabzon, Turkey. 445 pp.

CEH. 2004. Information Sheet 11: Australian Swamp Stonecrop. Center for Ecology and Hydrology (CEH), Natural Environment Research Council, Centre for Aquatic Plant Management, Wallingford, United Kingdom.

Dana, E. D., Sanz-Elorza, M. & Sobrino, E. 2002. Plant invaders in Spain (checklist): The unwanted citizens. University of Almeria, Department of Plant Biology and Ecology. Last accessed http://www.ual.es/personal/edana/alienplants/.

Dawson, F. H. 1989. Natural habitat and population control mechanism of *Crassula helmsii* (Australian Swamp Stonecrop) in Australia. Freshwater Biological Association, Ambleside, United Kingdom. 33 pp.

Dawson, F. H. 1994. Spread of *Crassula helmsii* in Britain. Pages 1-14 *in* L. C. de Waal, L. E. Child, P. M. Wade, and J. H. Brock, (eds.). Ecology and management of invasive riverside plants. John Wiley & Sons, New York, New York.

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

EPPO. 2013. PQR - EPPO's Plant Quarantine Data Retrieval System Version 5.0. European and Mediterranean Plant Protection Organization (EPPO), Paris, France.

Friday, J. T. 2013. Aquatic plants body backs plant bans but wary of further action. Horticulture Week, London, United Kingdom. Last accessed September 26, 2013, http://www.hortweek.com/news/1181333/aquatic-plants-body-backs-plant-bans-wary-further-action/.

GBIF. 2013. Data Portal. Global Biodiversity Information Facility (GBIF). Last accessed May 1, 2013, http://data.gbif.org/welcome.htm.

Heap, I. 2013. The International Survey of Herbicide Resistant Weeds Last accessed August 12, 2013, http://www.weedscience.org.

Heide-Jørgensen, H. S. 2008. Parasitic Flowering Plants. Brill Publishers, Leiden, The Netherlands. 442 pp.

IPPC. 2012. International Standards for Phytosanitary Measures No. 5: Glossary of Phytosanitary Terms. Food and Agriculture Organization of the United Nations, Secretariat of the International Plant Protection Convention (IPPC), Rome, Italy.

ISSG. 2013. Global Invasive Species Database. The World Conservation Union Species Survival Commission, Invasive Species Specialist Group (ISSG). http://www.issg.org/database/welcome/. (Archived at PERAL).

Java Aquatic Plants. 2013. *Crassula helmsii*. Java Aquarium Planting Ltd, Lisburn, United Kingdom. Last accessed September 19, 2013, http://www.java-plants.com/product_info.php?products_id=118.

Jones, L. A. 2011. Anatomical adaptations of four *Crassula* species to water availability. Bioscience Horizons 4(1):13-22.

Kartesz, J. T. 2013. North American Plant Atlas [maps generated from Kartesz, J.T. 2010. Floristic Synthesis of North America, Version 1.0. Biota of North America Program (BONAP). (in press)]. The Biota of North America Program, Chapel Hill, N.C. http://www.bonap.org/MapSwitchboard.html. (Archived at PERAL).

Kinver, M. 2013. UK bans sale of five invasive non-native aquatic plants. BBC News. January 28, 2013. Available from http://www.bbc.co.uk/news/science-environment-21232108.

Klavsen, S. K., and S. C. Maberly. 2009. Crassulacean acid metabolism contributes significantly to the in situ carbon budget in a population of the invasive aquatic macrophyte *Crassula helmsii*. Freshwater Biology 54(1):105-118.

Koop, A., L. Fowler, L. Newton, and B. Caton. 2012. Development and validation of a weed screening tool for the United States. Biological Invasions 14(2):273-294.

Kupper, H., B. Gotz, A. Mijovilovich, F. C. Kupper, and W. Meyer-Klaucke. (Research Support, Non-U.S. Gov't). 2009. Complexation and toxicity of copper in higher plants. I. Characterization of copper accumulation, speciation, and toxicity in *Crassula helmsii* as a new copper accumulator. Plant physiology 151(2):702-714.

Langdon, S. J., R. H. Marrs, C. A. Hosie, H. A. McAllister, K. M. Norris, and J. A. Potter. 2004. *Crassula helmsii* in U.K. Ponds: Effects on Plant Biodiversity and Implications for Newt Conservation. Weed Technology 18(ArticleType: research-article / Issue Title: Invasive Weed Symposium / Full publication date: 2004 / Copyright © 2004 Weed Science Society of America):1349-1352.

Lansdown, R. V. 2012. New Zealand Pigmyweed, *Crassula helmsii*. Great Britain Non-Native Species Secretariat (NNSS), York, United Kingdom. Last accessed September 26, 2013, https://secure.fera.defra.gov.uk/nonnativespecies/factsheet/factsheet.cfm?speciesId=1017.

Laundon, J. R. 1961. An Australasian species of *Crassula* introduced into Britain. Watsonia 2:59-63.

Mabberley, D. J. 2008. Mabberley's Plant-Book: A Portable Dictionary of Plants, their Classification and Uses (3rd edition). Cambridge University Press, New York, New York. 1021 pp.

Martin, P. G., and J. M. Dowd. 1990. A protein sequence study of the dicotyledons and its relevance to the evolution of the legumes and nitrogen fixation. Australian Systematic Botany 3:91-100.

Minchin, D. 2008. *Crassula helmsii*. Delivering Alien Invasive Species Inventories Europe (DAISIE). Available from http://www.europealiens.org/default.do. 3 pp.

NGRP. 2013. Germplasm Resources Information Network (GRIN). United States Department of Agriculture, Agricultural Research Service, National Genetic Resources Program (NGRP). http://www.ars-grin.gov/cgi-bin/npgs/html/index.pl?language=en. (Archived at PERAL).

Nickrent, D. 2009. Parasitic plant classification. Southern Illinois University Carbondale, Carbondale, IL, U.S.A. Last accessed June 12, 2009, http://www.parasiticplants.siu.edu/ListParasites.html.

ODA. 2007. Western US Invasive Plant EDRR Weed ID Guide. Oregon Department of Agriculture (ODA), and US Department of Agriculture, Salem, OR, U.S.A. 96 pp.

OEPP/EPPO. 2007. Data sheets on quarantine pests. *Crassula helmsii*. EPPO Bulletin 37:225-229.

Randall, R. P. 2012. A Global Compendium of Weeds. 2nd edition. Department of Agriculture and Food, Western Australia, South Perth, Australia. 1119 pp.

Reynolds, S. C. P. 2002. A Catalogue of Alien Plants in Ireland. National Botanic Gardens, Glasnevin, Ireland. 315 pp.

Ricketts, T. H., E. Dinerstein, D. M. Olson, and C. J. Loucks. 1999. Terrestrial Ecoregions of North America: A Conservation Assessment. Island Press. 485 pp.

Riemer, D. N. 1993. Introduction to Freshwater Vegetation. Krieger, Malabar, Florida. 205 pp.

Scott, R. W., and F. A. Huff. 1997. Lake effects on climatic conditions in the Great Lakes Basin. Contract Report 617 (MCC Research Report 97-01). Office of Applied Climatology, Illinois State Water Survey, Champaign, Illinois. 73 pp.

Spencer-Jones, D. 1994. Some observations on the use of herbicides for control of *Crassula helmsii*. Pages 15-18 *in* L. C. de Waal, L. E. Child, P. M. Wade, and J. H. Brock, (eds.). Ecology and management of invasive riverside plants. John Wiley & Sons, New York, New York.

Stokes, K., K. O'Neill, and R. A. McDonald. 2004. Invasive Species in Ireland. Environment & Heritage Service and National Parks & Wildlife Service, Belfast, Ireland. 153 pp.

The National Trust Conservation Newsletter. 2004. Chemical control of Australian swamp stonecrop (New Zealand Pygmy Weed) *Crassula helmsii*. The National Trust Conservation Newsletter 8:2-3.

The Wild Flower Society. 2013. Plant Life Survey. Invasive species. The Wild Flower Society, Kent, United Kingdom. Last accessed http://www.thewildflowersociety.com/wfs_new_pages/1z_news_27_06_06_plantlife_invaders.htm.

University of Queensland. 2011. Shade crassula. *Crassula multicava* subsp. *multicava*. Queensland Government and Weeds of Australia, Biosecurity Queensland Edition. Last accessed September 19, 2013, http://keyserver.lucidcentral.org/weeds/data/03030800-0b07-490a-8d04-0605030c0f01/media/Html/Crassula_multicava_subsp._multicava.htm

Veitch, C. R., and M. N. Clout. 2002. Turning the Tide: The Eradication of Invasive Species (Proceedings of the International Conference on Eradication of Island Invasives): Occasional Paper of the IUCN Species Survival Commission No. 27. The World Conservation Union (IUCN), SSC Invasive Species Specialist Group. vii + 414 pp.

Waterland Management Ltd. 2013. Submerged Rooted Plants. *Crassula helmsii*. Vines Farm, Berkshire, United Kingdom. Last accessed September 20, 2013, http://www.water-land.co.uk/submerged%20rooted%20weeds.htm.

Weber, E. 2003. Invasive Plant Species of the World: A Reference Guide to Environmental Weeds. CABI Publishing, Wallingford, UK. 548 pp.

Wild About Britain. 2010. *Crassula helmsii* - seek out and destroy? Water Life Forums, Wild About Britain Last accessed September 11, 2013, http://www.wildaboutbritain.co.uk/forums/water-life-forums/67273-crassula-helmsii-seek-out-and-destroy.html.

Wood, S. 2013. Getting swamped: Australian swamp stonecrop (*Crassula helmsii*) in the UK. CABI invasives blog. Last accessed September 11, 2013, http://cabiinvasives.wordpress.com/2013/05/17/getting-swamped-australian-swamp-stonecrop-crassula-helmsii-in-the-uk/.

Appendix A. Weed risk assessment for *Crassula helmsii* (Kirk) Cockayne (Crassulaceae). The following information came from the original risk assessment, which is available upon request (full responses and all guidance). We modified the information to fit on the page.

Question ID	**Answer - Uncertainty**	**Score**	**Notes (and references)**
ESTABLISHMENT/SPREAD POTENTIAL			
ES-1 (Status/invasiveness outside its native range)	f - negl	5	*Crassula helmsii* is native to Australia and New Zealand, and has been introduced to and become naturalized in the United Kingdom (NGRP, 2013), Ireland (Reynolds, 2002), Spain (Dana, 2002), France (Brunel et al., 2010), Belgium (Dawson and Warman, 1987), Denmark (OEPP/EPPO, 2007), Germany (Dawson, 1994), and the Netherlands (Brouwer and den Hartog, 1996). Widespread in the United Kingdom (OEPP/EPPO, 2007). Became naturalized in the United Kingdom after being sold as a plant for outdoor ponds (Laundon, 1961). A naturalized population of *C. helmsii* was first detected in a pond in Great Britain in 1956; by 1987 this plant had spread to about 100 sites and was described as being common or "frequently dominant" in a number of nature reserves (Dawson and Warman, 1987). By 1994 this plant had spread to 390 sites across Great Britain, and isoenzyme analysis has indicated that all of these populations likely came from a single introduction into Great Britain (Dawson, 1994). The alternate answers for the Monte Carlo simulation were both "e."
ES-2 (Is the species highly domesticated)	n - low	0	We found no evidence any cultivars of this plant exist or that this plant has been selectively bred for reduced weed potential. Plants are sold under the species name (Java Aquatic Plants, 2013).
ES-3 (Weedy congeners)	y - negl	1	Crassula is a genus of about 200 species (Mabberley, 2008). A few dozen species are reported as weeds (Randall, 2012). *Crassula multicava* is targeted for control in New Zealand and Australia because it prevents the regeneration of native species (University of Queensland, 2011; Veitch and Clout, 2002).
ES-4 (Shade tolerant at some stage of its life cycle)	y - negl	1	"High light levels seem to be required for good growth and plants become sparse generally in areas shaded by overhanging trees and bushes. At one site..., however, thick healthy submerged growth was observed despite shading, not only by trees but by a thin covering of *Lemna minor*" (Dawson and Warman, 1987). *Crassula helmsii* has been found growing 3 meters in depth underwater (Dawson and Warman, 1987) where only very low amounts of sunlight can reach the plants (Riemer, 1993). *Crassula helmsii* plants were found in a pond in Great Britain growing beneath a mat of *Lemna minor* (Laundon, 1961). In Australia, *Crassula helmsii* has been found growing in "streams...densely shaded by native woodland" (Dawson, 1989). "*Crassula helmsii* is tolerant of shade for long periods" (The National Trust Conservation Newsletter, 2004). Grows in and on the margins of swamps in mud or water (Laundon, 1961). "It does require high light (although according to the photosynthetic studies... light saturation point of emerged plants is only at 250-300 µmol photons m^2 s^{-1}, which is not really high) levels" (ISSG, 2013).
ES-5 (Climbing or smothering growth form)	n - low	0	*Crassula helmsii* is a succulent aquatic herb in the family Crassulaceae (Laundon, 1961). While dense populations of *C. helmsii* can smother vegetation (Dawson and Warman, 1987), individual plants do not have a climbing or smothering growth habit. Thus, we answered no for this question.

ES-6 (Forms dense thickets)	y - negl	2	"*Crassula helmsii* formed a dense 'mat' covering several square yards" (Laundon, 1961). "The habit [in shallow water] is frequently a dense sward growth....short dense stands of matted stems.…which can form a turf-like mat....and also forms dense mats...on damp soils besides fresh water" (Dawson and Warman, 1987).
ES-7 (Aquatic)	y - negl	1	Obligate aquatic that flowers and fruits in water (Dawson and Warman, 1987). Grows in swamps on damp mud, in shallow water, or completed submerged (Laundon, 1961). Able to grow submerged in still water down to 3 meters in depth (Dawson and Warman, 1987). "[I]t prefers to grow at water level but can tolerate varying water levels of many meters in moist conditions....the main limit to growth in Australia seemed to be drying" (Dawson, 1989).
ES-8 (Grass)	n - negl	0	*Crassula helmsii* is not a grass; it is a herbaceous plant in the family Crassulaceae (NGRP, 2013).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	*Crassula helmsii* is a succulent perennial herb in the family Crassulaceae (Laundon, 1961), a family not known to contain nitrogen-fixing species (Martin and Dowd, 1990).
ES-10 (Does it produce viable seeds or spores)	y - high	1	In its native Australia, *C. helmsii* produces a small amount of seeds with low viability (Dawson, 1989), but it is unclear if *C. helmsii* can produce viable seeds in its introduced range in the U.K. (OEPP/EPPO, 2007). "Simple tests for the viability of seeds were unsuccessful" (Dawson and Warman, 1987). "Germination trials on seeds…have not yet found the conditions or pretreatments necessary for germination to occur" (Dawson, 1994). "Seeds are not known to be produced in Europe" (Minchin, 2008).
ES-11 (Self-compatible or apomictic)	? - max	0	Unknown.
ES-12 (Requires special pollinators)	? - max		Unknown. "The flowers have a sweet nectar-like smell which is presumably associated with pollination; no specific animal was observed to act as a 'pollinator'" (Dawson and Warman, 1987).
ES-13 (Minimum generation time)	b - high	1	Broken stem fragments can grow into new plants, and in the autumn (in Great Britain), the plant apically produces short shoots called turions that act as vegetative propagules and disperse to colonize new areas (Dawson, 1994). "Fragments as small as one node (5 mm) can regrow" (CEH, 2004). Growth is mainly by vegetative spread (Dawson and Warman, 1987). "[P]erennial herb" (Laundon, 1961). In New Zealand, *C. helmsii* flowers in November and December, and rarely into February. In Great Britain, this species flowers in August and September (Laundon, 1961). Based on when this plant produces turions in the United Kingdom, we answered "b," but we used high uncertainty. The alternate answers for the Monte Carlo simulation were both "a."
ES-14 (Prolific reproduction)	n - high	-1	Each follicle has 2-5 seeds (Laundon, 1961). Carpels contain around 25 embryos (Dawson and Warman, 1987). "Flowering is profuse in…dry conditions" (Dawson and Warman, 1987). Based on this evidence, we answered no, but with high uncertainty because very little information is available regarding *C. helmsii* seed production.

ES-15 (Propagules likely to be dispersed unintentionally by people)	y - negl	1	Dawson (1987) states that the vegetative fragments of this plant can be dispersed by humans, including in fishing tackle, on nets and boats, and during stocking ponds with ornamental fish. *Crassula helmsii* can be spread to new areas by "fishing nets, during transfer of fish, emptying aquaria, [and] botanists and zoologists during surveys and pond clearance" (Dawson, 1994). "It is known that mistaken identity led to its introduction to replace *Crassula aquatica* at a site at which the latter no longer occurred" (Dawson and Warman, 1987). Vegetative propagules can be transported to new sites in mud (OEPP/EPPO, 2007).
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	y - low	2	"Dispersal may [occur] by the inclusion of fragments with other flora or fauna when stocking ornamental, recreational and fishing water bodies" (Dawson and Warman, 1987). "In addition, *C. helmsii* is often found as a 'contaminant' with other traded water plants" (OEPP/EPPO, 2007). The introduction of *C. helmsii* to the Isle of Wight may have been associated with the importation of sheep from Australia (Dawson, 1994).
ES-17 (Number of natural dispersal vectors)	3	2	Seed description used to answer ES-17a through ES-17e: "Follicles each with 2-5 seeds; seeds 0.5 x 0.2-0.3 mm., ellipsoid, often apiculate, brown, the testa smooth" (Laundon, 1961).
ES-17a (Wind dispersal)	n - low		Stem fragments are spread by wind over water surfaces (Dawson and Warman, 1987), but we found no evidence of the stem fragments or turions being dispersed in the air. Thus, we answered no.
ES-17b (Water dispersal)	y - negl		Stem fragments float and are carried to new areas in water (Dawson, 1994). "Seeds do not sink initially in water and could therefore be moved by...water currents" (Dawson and Warman, 1987). "Passive drift [of stem fragments] has occurred along canals and drains" (Dawson, 1994). "[E]asily dispersed by water" (Weber, 2003).
ES-17c (Bird dispersal)	y - high		Dawson (1987) states that Canada geese and herons could possibly disperse the stem fragments around ponds in Great Britain. "The possibility that the species can be dispersed by wading birds remains unproven" (OEPP/EPPO, 2007). Turions can be carried by birds (Minchin, 2008). We answered yes but used high uncertainty due to the conflicting information.
ES-17d (Animal external dispersal)	y - high		Dawson (1987) states that ponies could possibly disperse the stem fragments around ponds in Great Britain. May be dispersed by wildlife (Dawson, 1994). Can be spread by attaching to cattle (OEPP/EPPO, 2007). We used high uncertainty because our references were speculative.
ES-17e (Animal internal dispersal)	n - mod		We found no evidence of *C. helmsii* being dispersed internally by animals.
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	? - max	0	Unknown. Stem fragments tolerate drying and can remain viable for several weeks to 4 months (Dawson, 1994). "May overwinter as turions" (Minchin, 2008).

ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	y - negl	1	*Crassula helmsii* produces roots and lateral shoots from nodes when it is disturbed or stressed. "[I]t has an enormous potential to propagate from small fragments….Control by physical removal, often recommended, results in numerous propagules....plant control measures which broke up stems would enhance the chances of regrowth" (Dawson and Warman, 1987). "It can tolerate reasonable degrees of interferences such as trampling by cattle....It is able to colonise areas rapidly e.g. following fire" (Dawson, 1989). "DO NOT PRACTICE MECHANICAL CONTROL ON THIS PLANT. The fragments that are produced by cutting and tearing can regrow and spread the infestation downstream or re-infest the treated area" (CEH, 2004).
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	y - high	1	Resistant to copper (Kupper et al., 2009). Possible resistance to acrolein (Dawson, 1989). Not listed by Heap (2013). Diquat can effectively control *C. helmsii*, but if the plants are not fully killed the dying stems can release actively growing fragments that rapidly recolonize the area. Glyphosate can kill *C. helmsii* plants when larger than normally accepted doses are used (Dawson, 1994). Hydrogen peroxide has not effectively controlled this plant (Dawson, 1994). Repeated herbicide applications can effectively control *C. helmsii* (Spencer-Jones, 1994). Because *C. helmsii* is resistant to copper, we answered yes, but used high uncertainty because herbicides can be effective at controlling this plant when used repeatedly.
ES-21 (Number of cold hardiness zones suitable for its survival)	5	0	
ES-22 (Number of climate types suitable for its survival)	7	2	
ES-23 (Number of precipitation bands suitable for its survival)	11	1	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	n - mod	0	No evidence found.
Imp-G2 (Parasitic)	n - negl	0	*Crassula helmsii* is in the family Crassulaceae, a family not known to contain parasitic plant species (Heide-Jørgensen, 2008; Nickrent, 2009).
Impacts to Natural Systems			
Imp-N1 (Change ecosystem processes and parameters that affect other species)	y - negl	0.4	"Severe oxygen depletion can occur below dense growths of this plant...dense infestations cause severe fluctuations in dissolved oxygen content of the water and [grass carp] do not usually survive." (CEH, 2004). "Dense infestations of *Crassula helmsii* can...deplete the waters of oxygen resulting in competition for limiting resources" (Stokes et al., 2004). "It impoverishes the ecosystem for invertebrates and fish" (Brunel, 2005; ODA, 2007). "Forms dense...mats that can...result in oxygen depletion of the underlying water causing a decline in invertebrates, frogs, newts and fishes" (Minchin, 2008).

Imp-N2 (Change community structure)	y - high	0.2	*Crassula helmsii* forms dense, monotypic stands (Dawson and Warman, 1987; Dawson, 1994) and thus eliminate the structural diversity of a community. Based on this evidence, we answered yes but used high uncertainty because structural impacts were not explicitly stated in the literature.
Imp-N3 (Change community composition)	y - negl	0.2	"[S]mothers out other flora" (Dawson and Warman, 1987). "[A]ggressive competition with other aquatic species to their near exclusion....Competition between *C. helmsii* and other species was intense and resulted in the almost total suppression of native plants within a few years" (Dawson and Warman, 1987). "[S]mothers out other species, as *C. helmsii* remains throughout the year and shoots or germinating seeds of other species have difficulty in penetrating the stand. After as little as two years, many species can no longer penetrate these mats and are outcompeted" (Dawson, 1994). This plant does not go dormant, "enabling it to outpace native species which die back each winter" (OEPP/EPPO, 2007). *Crassula helmsii* utilizes Crassulacean acid metabolism (CAM) (Jones, 2011; Klavsen, 2009) "which enables it to take up CO_2 during the night and gives it a significant competitive advantage over other macrophytes. This is especially beneficial as aquatic environments generally have limited inorganic carbon" (ISSG, 2013).
Imp-N4 (Is it likely to affect federal Threatened and Endangered species)	y - low	0.1	"*C. helmsii* has so far invaded more marginal areas…and has in consequence come into conflict with rare plants in at least ten reserves" (Dawson and Warman, 1987). *Crassula helmsii* reduces the breeding success of the protected great crested newt in the United Kingdom by reducing native aquatic plant species populations used by the newts during egg-laying (Langdon et al., 2004; OEPP/EPPO, 2007). "The starfruit *Damasonium alisma*, one of the rarest plants in the United Kingdom, is thought to be threatened by *C. helmsii*" (OEPP/EPPO, 2007).
Imp-N5 (Is it likely to affect any globally outstanding ecoregions)	y - low	0.1	*Crassula helmsii* impacts native species (see impacts in Imp-N1 and Imp-N3) and invades waterways, which are often sensitive regions (Ricketts et al., 1999). Based on the results of the geopotential section, this plant may be able to impact sensitive globally outstanding ecoregions in the United States, such as the Florida Everglades (Ricketts et al., 1999).
Imp-N6 (Weed status in natural systems)	c - negl	0.6	Manually removing plants, shading the water with a dark fabric, and using approved herbicides are recommended for the control of *C. helmsii* in natural bodies of water such as reserves (Dawson and Warman, 1987). It is controlled in conservation areas in the United Kingdom (The National Trust Conservation Newsletter, 2004). Novel treatments such as using hot foam and burying the plants have been tested in conservation areas (Bridge, 2005). The alternate answers for the Monte Carlo simulation were both "b."
Impact to Anthropogenic Systems (cities, suburbs, roadways)			
Imp-A1 (Impacts human property, processes, civilization, or safety)	y - negl	0.1	"There are also occasional reports of death of pets which mistake carpets of New Zealand pygmyweed for land, jump onto the surface and are then unable to get out of the water and drown" (Lansdown, 2012), and these mats can also be dangerous to children (Brunel, 2005). In its native Australia, *C. helmsii* obstructs water flow in drainage channels (Dawson, 1989). Blocks outlet pipes and screens (Dawson, 1994). Chokes ponds and drainage ditches and may cause flooding (OEPP/EPPO, 2007). *Crassula helmsii* is the dominant plant in drainage channels (Dawson and Warman, 1987). Blocks ponds and drainage ditches (Brunel, 2005; ODA, 2007).

Imp-A2 (Changes or limits recreational use of an area)	y - low	0.1	"Strongly invaded waters lose their attractiveness for recreation" (OEPP/EPPO, 2007). "Reduces opportunities for angling and interferes with navigation" (Minchin, 2008).
Imp-A3 (Outcompetes, replaces, or otherwise affects desirable plants and vegetation)	y - mod	0.1	"The dominant submerged plant of one artificial managed lake...changed totally within two years from *Elodea* spp. to *C. helmsii*" (Dawson and Warman, 1987).
Imp-A4 (Weed status in anthropogenic systems)	c - negl	0.4	Herbicides, grass carp, and draining have been used to control *C. helmsii* in private and commercial bodies of water (Dawson and Warman, 1987). Herbicides are used to control *C. helmsii* in drainage channels in Australia (Dawson, 1989). Herbicide trials have been conducted to control *C. helmsii* in private lakes (Spencer-Jones, 1994). Controlled in garden ponds (Wild About Britain, 2010). The alternate answers for the Monte Carlo analysis were both "b."
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	n - mod	0	We found no evidence.
Imp-P2 (Lowers commodity value)	y - high	0.2	"Mike Heylin, from Angling Trust, says 'New Zealand Pigmyweed…can extend over the whole surface of ponds and rivers, excluding light to the fish and invertebrates living below the surface and ultimately killing the water as a fishery'" (Angling Trust, 2009). Forms vegetative mats that "can be dangerous to...livestock…who mistake them for dry land" (ODA, 2007).
Imp-P3 (Is it likely to impact trade)	y - low	0.2	Vegetative propagules of *C. helmsii* can contaminate traded water plants (OEPP/EPPO, 2007) as well as water used during stocking fishing water bodies (Dawson and Warman, 1987). *Crassula helmsii* has been banned from sale in the United Kingdom (Kinver, 2013; Wood, 2013), and is regulated as an invasive alien plant in Poland and Switzerland (EPPO, 2013). Based on this information, it seems likely that *C. helmsii* could impact trade if it became naturalized in the United States.
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	? - max		We found no evidence of this plant impacting irrigation water, but *C. helmsii* seems likely to have this impact based on its ability to block drainage ditches (Dawson, 1989; Dawson, 1994; OEPP/EPPO, 2007). Thus, we answered unknown for this impact.
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - mod	0	Grass carp can eat small infestations of *C. helmsii* (CEH, 2004; Dawson and Warman, 1987). "Animals are known to consume *Crassula helmsii*" (ISSG, 2013). No specific grazers known (Minchin, 2008). Based on this evidence, we answered no.
Imp-P6 (Weed status in production systems)	b - mod	0.2	"[I]n the U.K….its growth interferes with the use of fisheries" (Dawson, 1989). We found no evidence that *C. helmsii* is controlled in agricultural areas, so we answered "b." The alternate answers for the Monte Carlo analysis were "c."
GEOGRAPHIC POTENTIAL			Information below is point source data from GBIF (GBIF, 2013) unless otherwise specified.
Plant cold hardiness zones			
Geo-Z1 (Zone 1)	n - negl	N/A	We found no evidence that *C. helmsii* grows in this zone.
Geo-Z2 (Zone 2)	n - negl	N/A	We found no evidence that *C. helmsii* grows in this zone.
Geo-Z3 (Zone 3)	n - low	N/A	Dawson (1987) reported that *C. helmsii* grows in the Baikal Region of Russia, but we found no additional evidence for that. Thus, we answered no for this zone, but raised our uncertainty.

Geo-Z4 (Zone 4)	n - low	N/A	We found no evidence that *C. helmsii* grows in this zone.
Geo-Z5 (Zone 5)	n - low	N/A	We found no evidence that *C. helmsii* grows in this zone.
Geo-Z6 (Zone 6)	n - mod	N/A	We found no evidence that *C. helmsii* grows in this zone.
Geo-Z7 (Zone 7)	y - negl	N/A	Germany.
Geo-Z8 (Zone 8)	y - negl	N/A	United Kingdom.
Geo-Z9 (Zone 9)	y - negl	N/A	United Kingdom.
Geo-Z10 (Zone 10)	y - negl	N/A	Ireland, United Kingdom.
Geo-Z11 (Zone 11)	y - negl	N/A	Australia.
Geo-Z12 (Zone 12)	n - high	N/A	We found no evidence that *C. helmsii* grows in this zone.
Geo-Z13 (Zone 13)	n - mod	N/A	We found no evidence that *C. helmsii* grows in this zone.
Köppen-Geiger climate classes			
Geo-C1 (Tropical rainforest)	n - mod	N/A	We found no evidence that *C. helmsii* grows in this climate class.
Geo-C2 (Tropical savanna)	n - mod	N/A	We found no evidence that *C. helmsii* grows in this climate class.
Geo-C3 (Steppe)	y - negl	N/A	Australia.
Geo-C4 (Desert)	y - mod	N/A	Australia.
Geo-C5 (Mediterranean)	y - negl	N/A	Australia.
Geo-C6 (Humid subtropical)	y - negl	N/A	Australia.
Geo-C7 (Marine west coast)	y - negl	N/A	Ireland and the United Kingdom.
Geo-C8 (Humid cont. warm sum.)	y - high	N/A	We did not find any occurrences in this climate class, but this may be because this climate class does not occur in *C. helmsii*'s native range and where it has been introduced. Based on the biology of this plant and its ability to grow in the humid continental cool summers climate zone and warmer climate zones, we answered yes, but with high uncertainty.
Geo-C9 (Humid cont. cool sum.)	y - negl	N/A	Germany and Denmark.
Geo-C10 (Subarctic)	n - mod	N/A	We found no evidence that *C. helmsii* grows in this climate class.
Geo-C11 (Tundra)	n - negl	N/A	We found no evidence that *C. helmsii* grows in this climate class.
Geo-C12 (Icecap)	n - negl	N/A	We found no evidence that *C. helmsii* grows in this climate class.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	y - mod	N/A	"*C. helmsii* seems to be confined to areas that have levels of precipitation from 100 to 550 mm in summer (November–April) and 200–3000 mm in winter (May–October)" (OEPP/EPPO, 2007). Based on this evidence and the biology of this plant, we answered yes for this precipitation band.
Geo-R2 (10-20 inches; 25-51 cm)	y - negl	N/A	Australia.
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	Australia .
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	Australia .
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	Ireland and Australia.
Geo-R6 (50-60 inches; 127-152 cm)	y - negl	N/A	Australia (Tasmania).
Geo-R7 (60-70 inches; 152-178 cm)	y - negl	N/A	Australia (Tasmania).

Geo-R8 (70-80 inches; 178-203 cm)	y - negl	N/A	United Kingdom.
Geo-R9 (80-90 inches; 203-229 cm)	y - low	N/A	"*C. helmsii* seems to be confined to areas that have levels of precipitation from 100 to 550 mm in summer (November–April) and 200–3000 mm in winter (May–October)" (OEPP/EPPO, 2007). Based on this evidence and the biology of this plant, we answered yes for this precipitation band.
Geo-R10 (90-100 inches; 229-254 cm)	y - low	N/A	Same justification as that used for Geo-R9.
Geo-R11 (100+ inches; 254+ cm)	y - low	N/A	Same justification as that used for Geo-R9.
ENTRY POTENTIAL			
Ent-1 (Plant already here)	n - high	0	"Not known to be established in the U.S. outside of cultivation" (ODA, 2007). Not listed in the BONAP database (Kartesz, 2013) or by Bailey and Bailey (1976). Regulated as a noxious weed by Florida, Indiana, Minnesota, North Carolina, and Washington (NGRP, 2013). Reports of this plant in the United States (ISSG, 2013) are likely erroneous. Because we did not find any evidence that this plant is cultivated in the United States after searching numerous botanical and garden databases, we answered no, but with high uncertainty.
Ent-2 (Plant proposed for entry, or entry is imminent)	n - low	0	
Ent-3 (Human value & cultivation/trade status)	d - low	0.5	Available for sale online as an aquarium plant (Java Aquatic Plants, 2013).
Ent-4 (Entry as a contaminant)			
Ent-4a (Plant present in Canada, Mexico, Central America, the Caribbean or China)	n - low		We found no evidence that *C. helmsii* is present in these regions.
Ent-4b (Contaminant of plant propagative material (except seeds))	y - low	0.04	Vegetative propagules of *C. helmsii* can contaminate traded water plants (OEPP/EPPO, 2007).
Ent-4c (Contaminant of seeds for planting)	n - mod	0	We found no evidence that *C. helmsii* contaminates seeds.
Ent-4d (Contaminant of ballast water)	n - mod		We found no evidence that *C. helmsii* contaminates ballast water. It is a freshwater plant (Dawson, 1994).
Ent-4e (Contaminant of aquarium plants or other aquarium products)	y - low	0.02	*Crassula helmsii* is a contaminant of water plants (OEPP/EPPO, 2007). *Crassula helmsii* can be spread to new areas via emptied aquaria (Dawson, 1994).
Ent-4f (Contaminant of landscape products)	y - low	0.02	*Crassula helmsii* can be dispersed in water during stocking ponds with ornamental fish (Dawson and Warman, 1987).
Ent-4g (Contaminant of containers, packing materials, trade goods, equipment or conveyances)	y - low	0.02	Turions can be transported to new sites by boats (Dawson and Warman, 1987) and in mud (OEPP/EPPO, 2007).

Ent-4h (Contaminants of fruit, vegetables, or other products for consumption or processing)	n - mod	0	We found no evidence that *C. helmsii* contaminates fruit and vegetables.
Ent-4i (Contaminant of some other pathway)	? - max		Unknown.
Ent-5 (Likely to enter through natural dispersal)	n - mod	0	We found no evidence.