Risk Assessment of *Myriophyllum aquaticum*

Name of Organism:	*Myriophyllum aquaticum* (Vellozo) Verdcourt – Parrot's Feather
Objective:	Assess the risks associated with this species in Ireland
Version:	Final 15/09/2014
Author(s)	Michael Millane and Joe Caffrey
Expert reviewer	Jonathan Newman

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About the risk assessment

This risk assessment is based on the **N**on-native species **AP**plication based **R**isk **A**nalysis (NAPRA) tool (version 2.66). NAPRA is a computer based tool for undertaking risk assessment of any non-native species. It was developed by the European and Mediterranean Plant Protection Organisation (EPPO) and adapted for Ireland and Northern Ireland by Invasive Species Ireland. It is based on the Computer Aided Pest Risk Analysis (CAPRA) software package which is a similar tool used by EPPO for risk assessment.

Notes: Confidence is rated as low, medium, high or very high.
Likelihood is rated as very unlikely, unlikely, moderately likely, likely or very likely.
The percentage categories are 0% - 10%, 11% - 33%, 34% - 67%, 68% - 90% or 91% - 100%.
N/A = not applicable.

This is a joint project by Inland Fisheries Ireland and the National Biodiversity Data Centre to inform risk assessments of non-native species for the European Communities (Birds and Natural Habitats) Regulations 2011. It is supported by the National Parks and Wildlife Service.

DOCUMENT CONTROL SHEET

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Version Control Table

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Stage 1 - Organism Information *The aim of this section is to gather basic information about the organism.*			
N	**QUESTION**	**RESPONSE**	**COMMENT**
1	What is the reason for performing the risk assessment?		A risk assessment is required as this species is listed as a "Non-native species subject to restrictions under Regulations 49 and 50" in the Third Schedule of the European Communities (Birds and Natural Habitats) Regulations 2011, SI 477/2011.
2	Identify the organism. Is it clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?	YES	*Myriophyllum aquaticum* (Vellozo) Verdcourt (preferred scientific name); *Enydria aquatica* Vellozo, *Myriophyllum brasiliense* Cambess., and *Myriophyllum proserpinacoides* Gillies ex Hook. & Arn. Parrot's Feather; Parrot Feather Watermilfoil, Water Feather; Brazilian Water Milfoil (EPPO 2005) and Parrotfeather (Sytsma and Anderson 1993a). According to GB Non-Native Species Secretariat (2011), *M. brasiliense* is considered a different species in the horticultural / aquarium trade and is considered less cold tolerant than *M. aquaticum*.
3	If not a single taxonomic entity, can it be redefined? (if necessary use the response box to re-define the organism and carry on)	N\A	
4	Describe the organism.		*Myriophyllum aquaticum* is a "stout aquatic or marsh-dwelling herb; stems to 2 m long, 4-5 mm diameter near base, glaucous, rooting freely from lower nodes, glabrous. Submerged leaves in whorls of (4-)5-6, oblanceolate in outline, rounded at apex (1.7-) 3.5-4.0 cm long, (0.4-) 0.8-1.2 cm wide, pectinate, with 25-30 linear pinnae up to 0.7 cm long, the lower leaves usually decaying rapidly. Emergent leaves glaucous, in whorls of (4-) 5-6, erect near apex, spreading in lower parts, narrowly oblanceolate in outline, rounded at apex, (1.5-) 2.5-3.5 cm long, (0.4 -) 0.7-0.8 cm wide, pectinate, with (18-) 24-36 pinnae in the upper four-fifths (lower 5-7 mm of rachis naked) pinnae linear to subulate, 4.5-5.5 mm long, 0.3 mm wide, tips very shortly apiculate, slightly incurved. Numerous hydathodes at base of leaves. Plants dioecious, males much less common than female throughout introduced range. Inflorescence an indeterminate spike with flowers singly borne in axils of upper emergent leaves, subtended by 2 bracteoles. Bracteoles subulate, 1.2-1.5 mm long with (1-) 2 short teeth in the lower-third, sometimes almost trifid. Flowers strictly unisexual. Male flowers tetramerous, sessile at first, with pedicels to 4 mm long usually developing at anthesis. Sepals 4, ovate-deltoid, 0.7-0.8 mm long, 0.3 mm wide, very weakly denticulate, smooth. Petals 4, yellow, weakly hooded and keeled, (2.3-) 2.7-3.1 mm long, 0.8-1.1 mm wide. Stamens 8; filaments 0.1 mm long at anthesis; lengthening later to up to 1.2 mm; anthers

Stage 1 - Organism Information *The aim of this section is to gather basic information about the organism.*			
N	**QUESTION**	**RESPONSE**	**COMMENT**
			yellow, linear-oblong (1.8-) 2.0-2.7 mm long, 0.2 mm wide, non-apiculate. Styles 0. Female flowers tetramerous, on pedicel 0.2-0.4 mm long. Sepals 4, white, deltoid, 0.4-0.5 mm long, 0.3 mm wide, denticulate with one to several small teeth on each margin, smooth. Petals 0. Stamens 0. Styles 4, clavate, 0.1-0.2 mm long, stigmas white, densely fimbriate. Ovary pyriform, 0.6-0.7 mm long, 0.6 mm wide, 4-ribbed longitudinally between sepals. Fruit (immature) on pedicel 0.7-0.8 mm long, cylindrical to ovoid, 1.7 mm long, 1.3-1.4 (-1.7) mm diameter. Sepals are first persistent, erect, deltoid, 0.6 mm long, 0.3 mm wide, toothed towards tip, withering at maturity. Mericarps cylindrical, 1.7 mm long, 0.6-0.7 mm diameter, slightly wider towards base, apex oblique, with an indistinct thickened rim, otherwise smooth, rounded on dorsal surface." (Orchard 1981 as cited in CABI 2007).
5	Does a relevant earlier risk assessment exist? (give details of any previous risk assessment)	YES	Two preliminary risk assessments were previously carried out for Ireland as follows. A stage one and two risk assessment as part of *Ireland's National Plant Conservation Strategy - Target 10 - Managing Invasive Alien Species* (Botanic Gardens 2007); and a prioritisation risk assessment as part of the *Risk Analysis and Prioritisation for Invasive and Non-native Species in Ireland and Northern Ireland* (Kelly *et al*. 2013). The former assessment designated *Myriophyllum aquaticum* as a "most significant invasive plant" and the latter assessment designed the plant as a 'high risk' invasive species for Ireland.
6	If there is an earlier risk assessment is it still entirely valid, or only partly valid?	PARTIAL	Only preliminary risk assessments were previously conducted in Ireland (refer to Question 5).
7	Where is the organism native?		South America (Argentina, Bolivia, Brazil, Chile, Ecuador, Paraguay and Peru) (reviewed in Global Invasive Species Database 2005).
8	What is the current global distribution of the organism (excluding Ireland)?		Africa (Botswana, Lesotho, Madagascar, Reunion, South Africa, Zambia and Zimbabwe), Asia (Cambodia, China, Java, Indonesia, Israel, Japan, Malaysia, Philippines, Taiwan, Thailand and Vietnam), Australia, Central America (Costa Rica and Nicaragua), Europe (Austria, Britain, France, Germany, Guernsey, Isle of Man, Northern Ireland, The Netherlands and Portugal), New Zealand, North America (Mexico and USA) and South America (Argentina, Bolivia, Brazil, Chile, Columbia, Ecuador, Paraguay, Peru and Uruguay). (reviewed in CABI 2014)

Stage 1 - Organism Information *The aim of this section is to gather basic information about the organism.*			
N	**QUESTION**	**RESPONSE**	**COMMENT**
9	What is the current distribution of the organism in Ireland?		*Myriophyllum aquaticum* is recorded in a total of 14 x 10km squares in Ireland (National Biodiversity Data Centre 2009). The majority of these records are from ponds in private estates or golf courses It was first recorded in the island of Ireland in Lough Neagh in 1984 (National Biodiversity Data Centre 2009).
10	Is the organism known to be invasive anywhere in the world?	YES	According to CABI (2007 and references therein), "Although usually benign in its native range, *M. aquaticum* can and does cause weed problems in South America. It is invasive in reservoirs in Brazil as far north as Rio de Janeiro State. It is now regarded as a major international aquatic weed, having been introduced to much of the warm-temperate to sub-tropical regions of the world. The weed is aggressively spreading in southern Africa, as far north as Zambia. It causes severe problems in southern states of the USA (and increasingly as far north as Oregon, Washington and New England, New Zealand and Australia, and southern Europe (Portugal and France). It occurs and occasionally causes problems (with a trend towards increasing severity and occurrence of infestations, possibly associated with a trend towards warmer winters) in cooler regions of central Europe and the British Isles. It was designated a Rank A Invasive Alien Species (i.e. included among the 16 most invasive weeds) in Japan in 2004". *Myriophyllum aquaticum* has been recently banned for sale in England (in April 2014) and is considered a problematic invasive there (GB Non-Native Species Secretariat 2011).

Stage 2 - Detailed assessment: Section A - Entry

This section evaluates the probability of entry of an organism into Ireland. For organisms which are already present, only complete the entry section for currently active pathways of entry and potential future pathways. The entry section need not be completed for pathways which have allowed an organism to enter in the past but are no longer active.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.01	How many active/future pathways are relevant to the potential entry of this organism (n/a, very few, few, moderate number, many or very many)?	MANY	VERY HIGH	Horticultural and aquarium trade, boating, angling and other water activities.
1.02	List significant pathways through which the organism could enter. Where possible give detail about the specific origins and end points of the pathways.	1. Horticultural and aquarium trade 2. Boating, angling and other water activities		*Myriophyllum aquaticum* is imported into Ireland *via* the horticultural and aquarium sectors for sale to the public in garden centres and aquarium / pet shops. It is also sold periodically in some other retail outlets, such as supermarkets, and is available to buy on the internet. The risk of introduction by boats and anglers arises from any travel to Ireland from an infested area abroad where equipment is inadvertently contaminated with viable plant material.

Pathway 1 - Horticultural and aquarium trade

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.03	Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (e.g. the organism is a contaminant of imported goods)?	INTENTIONAL	VERY HIGH	*Myriophyllum aquaticum* is deliberately imported for trade.
1.04	How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?	LIKELY	MEDIUM	*Myriophyllum aquaticum* is deliberately imported for trade and subsequently sold in a wide range of outlets in Ireland as an oxygenator / ornamental weed for artificial watercourses, garden ponds and aquaria. In Britain, the number of plants in the trade per annum is estimated to be *c.* 20,000 (GB Non-Native Species Secretariat 2011).
1.05	How likely is the organism to enter Ireland undetected or without the knowledge of relevant competent authorities?	VERY LIKELY	VERY HIGH	Awareness by the relevant competent authorities at points of entry to recognise and identify this species is limited or non-existent at present.
1.06	How likely is the organism to survive during passage along the pathway?	VERY LIKELY	VERY HIGH	As the organism is distributed deliberately *via* trade, survival is considered very likely.

Pathway 1 - Horticultural and aquarium trade				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
1.07	How likely is the organism to arrive during the months of the year appropriate for establishment?	VERY LIKELY	VERY HIGH	In Britain, the plant is sold in springtime for planting in garden ponds (GB Non-Native Species Secretariat 2011) and this is also likely to be the case in Ireland. *Myriophyllum aquaticum* solely reproduces asexually outside of its native range through vegetative fragmentation or *via* rhizomes (Global Invasive Species Database 2005). The plant does not auto-fragment and viable fragments typically arise from some kind of mechanical disturbance (e.g. wave or wind action or human interference) (Washington State, Department of Ecology 2003). The majority of growth occurs in summer and plants eventually die back to over-winter as rhizomes. In the spring, rapid growth from the over-wintering rhizomes re-commences when water temperatures start to increase (Global Invasive Species Database 2005). The plant may have difficulty establishing or surviving in exceptionally cold winters in Ireland as it is considered to have a low tolerance, at least, to continental European winters. However, in the UK, it has been observed to survive 'most winters' (GB Non-Native Species Secretariat 2011). Further to this, observations from Britain suggest that only the emergent parts of the plant appear to be susceptible to frost or ice damage and impacted plants can regrow from submerged material (GB Non-Native Species Secretariat 2011). Rhizomes have been shown to remain viable for one year after storage under moist conditions in a refrigerator (Sytsma and Anderson 1993a).
1.08	How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	LIKELY	HIGH	Ireland has a high density and abundance of natural freshwaters, many of which are suitable for the establishment of *Myriophyllum aquaticum*. The plant is typically found in slow-moving or static waters including lakes, reservoirs, ponds, slow-flowing rivers (notably in their back waters), canals, fens, ditches and irrigation channels. It is particularly suited to eutrophic conditions and has some tolerance to brackish water (Centre for Ecology and Hydrology 2004; CABI 2007; GB Non-Native Species Secretariat 2011). *Myriophyllum aquaticum* is normally deliberately introduced to the wild by man (GB Non-Native Species Secretariat 2011). The practice of planting *Myriophyllum aquaticum* in artificial watercourses or ponds, which can sometimes be proximal to receptive natural systems, and its use in aquaria, increases the likelihood of it transferring from this pathway to a suitable habitat either by natural spread or from the disposal

Pathway 1 - Horticultural and aquarium trade				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
				of vegetative material into the wild. This pathway may also facilitate the deliberate introduction or planting of *Myriophyllum aquaticum* into water bodies. However, there is no evidence that this has occurred to date in Ireland.
1.09	Estimate the overall likelihood of entry into Ireland based on this pathway?	VERY LIKELY	VERY HIGH	It is already deliberately imported for trade.
1.10	Do other pathways need to be considered?	YES		

Pathway 2 – Boating, angling and other water activities.				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
1.03	Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (e.g. the organism is a contaminant of imported goods)?	ACCIDENTAL	VERY HIGH	The overland or cross-channel movement of boats, boat trailers, boat engines, angling gear and other items used in water activities from an infested to uninfested area has the potential to inadvertently spread this organism if viable plant material is attached. This includes the import of used boats from abroad.
1.04	How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?	UNLIKELY	HIGH	In the absence of implementing appropriate biosecurity measures, there is an increased potential for the inadvertent spread of viable plant material overland from infested to uninfested waters. It is unlikely that 'large numbers' of *Myriophyllum aquaticum* plants will travel along this pathway but occasional transfer of this species by this pathway is possible.
1.05	How likely is the organism to enter Ireland undetected or without the knowledge of relevant competent authorities?	VERY LIKELY	VERY HIGH	Awareness by the relevant competent authorities at points of entry to recognise and identify this species is limited or non-existent at present.

Pathway 2 – Boating, angling and other water activities.				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
1.06	How likely is the organism to survive during passage along the pathway?	LIKELY	HIGH	Survival along this pathway is ultimately dependent on environmental conditions and duration of transport. It is considered that viable plant material can survive in a damp environment on equipment for at least several days. A study by Barnes *et al*. (2013) found that *Myriophyllum aquaticum* has a high desiccation tolerance compared to nine other common aquatic plant species tested. After 3 hours of active drying (i.e. in front of a box fan to simulate overland dispersal *via* hitch-hiking) at *c*. 25^{o}C, all plant fragments tested remained viable.
1.07	How likely is the organism to arrive during the months of the year appropriate for establishment?	LIKELY	HIGH	Boating, angling and other water activities are not necessarily restricted to a particular season and may occur throughout the year. Viable plant material could be inadvertently transferred from colonised to uncolonised areas *via* this pathway at any time of year (refer to response to Pathway 1, Question 1.07 for details on plant lifecycle stage at different times of year).
1.08	How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	MODERATELY LIKELY	HIGH	As noted in Pathway 1 , Question 1.08, Ireland has a high density and abundance of natural freshwaters, many of which are suitable for the establishment of *Myriophyllum aquaticum*. The movement of boats, boat trailers, boat engines, angling gear and other items used in water activities can act as a direct pathway to transfer this organism from an infested water to a suitable habitat elsewhere. As *Myriophyllum aquaticum* has a high resilience to desiccation (Barnes *et al*. 2013), successful transfer would be dependent on the environmental conditions and duration of transport.

Pathway 2 – Boating, angling and other water activities.				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
1.09	Estimate the overall likelihood of entry into Ireland based on this pathway?	MODERATELY LIKELY	HIGH	This pathway depends on the transfer of viable plant material surviving an overland or cross-channel journey in association with the movement of boats, boat trailers, boat engines, angling gear and other items used in water activities from an infested water abroad to an uninfested water in Ireland. In Northern Ireland *Myriophyllum aquaticum* is recorded only in 6 x 10 km squares, but it is present in Lough Neagh (Kelly and Maguire 2009). In Britain, the plant is much more widespread, being present in 400 x 10 km squares and it has increasingly been found in natural freshwaters there since the 1990s (GB Non-Native Species Secretariat 2011). There is no specific data available on the movement of boats, boat trailers, boat engines, angling gear and other items used in water activities from infested areas abroad to Ireland. However, it is considered moderately likely that the organism can enter *via* this pathway from such areas.
1.10	Do other pathways need to be considered?	NO		

Overall likelihood				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
1.11	Estimate the overall likelihood of entry into Ireland based on all pathways (comment on the key issues that lead to this conclusion).	VERY LIKELY	VERY HIGH	The primary pathway of entry into Ireland is through deliberate trade *via* the horticultural and aquarium sectors. The movement of boats and anglers from infested areas outside Ireland into the country may also facilitate entry as viable plant material can potentially survive in a damp environment out of water for at least several days.

Stage 2 - Detailed assessment: Section B – Establishment

This section evaluates the probability of establishment of an organism within Ireland. For organisms which are already well established in Ireland there is no need to complete this section - move straight to the Spread section.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
2.01	Is the organism well established in Ireland (if there is any uncertainty answer 'unsure')	NO	VERY HIGH	*Myriophyllum aquaticum* is recorded in a total of 14 x 10km squares in Ireland (42 individual records; National Biodiversity Data Centre 2009). The majority of these records are from ponds in private estates or golf courses. It was first recorded on the island of Ireland in Lough Neagh in 1984 (National Biodiversity Data Centre 2009).
2.02	How likely is it that the organism will be able to establish in Ireland based on the similarity between local climatic conditions and the organism's current global distribution?	VERY LIKELY	VERY HIGH	*Myriophyllum aquaticum* has already demonstrated that it can establish in Ireland. In the majority of sites in the country where it is recorded, it grows with relatively low abundance and does not appear significantly adversely impact on resident macrophyte communities (J. Caffrey, personal observation. There are, however, two locations in Ireland where the plant has established dense, mono-specific stands (in a large ponds located in Fota Island, Co. Cork and in a large pond in Kilmeaden, Co. Waterford) (J. Caffrey, personal observation). Both locations are in the south of the country near the coast and, therefore, are likely subjected to less harsh winter conditions and frost events than other more inland populations (Met Éireann 2014). Such relatively mild climatic conditions may facilitate the establishment of more vigorous populations that are less hampered by periodic cold temperature damage. Typical water temperatures suitable for *Myriophyllum aquaticum* are reported to range from 5 to 20^{o}C with a wider tolerance of 2- 30^{o}C also recorded (CABI 2007). Suitable temperatures to maintain the plant are also found in the grey literature from aquaria-related websites e.g. 20 to 28^{o}C (FNZAS undated) or 10 to 29^{o}C (The Planted Tank undated). Alternatively, the Global Invasive Species Database (2005) states that *Myriophyllum aquaticum* “exists” in temperatures ranging from 16 to 23C.
2.03	How likely is it that the organism will be able to establish in Ireland based on the similarity between other local abiotic conditions and the organism's current global distribution?	VERY LIKELY	VERY HIGH	Based on its present occurrence in Ireland, it is very likely that there are no overriding abiotic factors to limit its further establishment in habitat types which are similar to those it occupies already in Ireland and throughout its global range. The typical pH for *Myriophyllum aquaticum* is reported to range from 7-9, and for salinity from 1.0 to 3.0 parts per thousand, with a tolerance of <1.0-10.0 parts per thousand (CABI 2007). Alternatively, the Global Invasive Species Database (2005) states that *Myriophyllum aquaticum* “exists” in a pH range of 6.8-8.0. Suitable pH to maintain the plant are

Stage 2 - Detailed assessment: Section B – Establishment

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				also found in the grey literature from aquaria related websites e.g. 6 to 7.2 (FNZAS undated) or 5 to 7.5 (The Planted Tank undated). Suitable water hardness is also noted as being from 30-150 ppm (FNZAS undated) or between 50 - 200 ppm (Global Invasive Species Database (2005).
2.04	How likely is the organism to encounter habitats necessary for the survival, development and multiplication of the organism in Ireland?	VERY LIKELY	VERY HIGH	As stated previously, Ireland has a high density and abundance of natural freshwaters susceptible to colonisation by *Myriophyllum aquaticum* which can facilitate its subsequent survival, development and multiplication. The plant is typically found in slow-moving or static waters including lakes, reservoirs, ponds, slow-flowing rivers (notably in their back waters), canals, fens, ditches and irrigation channels but not suited to fast flowing waters. It is particularly suited to eutrophic conditions and has some tolerance to brackish water (Centre for Ecology and Hydrology 2004; CABI 2007; GB Non-Native Species Secretariat 2011).
2.05	How likely is it that establishment will occur despite competition from existing species in Ireland?	VERY LIKELY	HIGH	*Myriophyllum aquaticum* has already demonstrated that it can establish in Ireland and there is no obvious indication that competition from existing species may hamper this. In the majority of sites in the country where it is recorded, it does not appear to adversely impact any resident macrophyte communities (J. Caffrey, personal observation. There are, however, two locations in Ireland (both of which are in the south of the country) where the plant has established dense, mono-specific stands (in a large ponds located in Fota Island, Co. Cork and in a large pond in Kilmeaden, Co. Waterford) (J. Caffrey, personal observation). Both locations are in the south of the country near the coast, and therefore, are subjected to less harsh winter conditions and frost events as other inland populations would be (Met Éireann 2014). In Britain, according to GB Non-Native Species Secretariat (2011), "The habitat preferences of floating and amphibious macrophytes do not overlap with many native species (except *Glyceria maxima*). Therefore, there is little competition from existing species" there. .
2.06	How likely is it that establishment will occur despite predators, parasites or pathogens already present in Ireland?	VERY LIKELY	HIGH	There are no known natural predators, parasites or pathogens of this species in Ireland that will have an adverse effect on its establishment.

Stage 2 - Detailed assessment: Section B – Establishment

This section evaluates the probability of establishment of an organism within Ireland. For organisms which are already well established in Ireland there is no need to complete this section - move straight to the Spread section.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
2.07	How likely is it that establishment will occur despite existing management practices?	UNLIKELY	HIGH	In general, the public management of waterways is increasingly undertaken cognisant of ensuring biosecurity measures are in place to mitigate for the spread of aquatic invasive species. An increase in awareness of the threat from aquatic invasive species by some private entities has also somewhat reduced this risk.
2.08	How likely is it that management practices in Ireland will facilitate the establishment of the organism?	UNLIKELY	HIGH	Refer to response to Question 2.07.
2.09	How likely is it that the biological characteristics of the organism would allow it to survive eradication campaigns in Ireland?	VERY LIKELY	HIGH	As only female plants are likely to be present in Ireland (as is the case in most of its introduced range), reproduction is solely by asexual means (CABI 2007). Mechanical control conducted with disregard for the generation of vegetative fragments will facilitate the survival and re-establishment in a treated area and increase the potential for spread to adjacent areas (Global Invasive Species Database 2005; CABI 2007). The absence of a capability to reproduce by sexual means and therefore maintain a seed reserve in infested habitats, increases the efficacy of the following two control methods. Light-excluding benthic barriers, such as jute matting, could bring about control in sites where *Myriophyllum aquaticum* colonisation is localised (Kelly and Maguire 2009; Caffrey *et al*. 2011; CAISIE 2013) but the efficacy of this approach has not been tested on this plant in Ireland to date. The eradication of low density infestations could be achieved *via* careful manual removal. The eradication of extensive infestations in large, open waters using this method would not be feasible.
2.10	How likely is it that the biological characteristics of the organism will facilitate its establishment?	LIKELY	HIGH	The ability of *Myriophyllum aquaticum* to reproduce asexually from vegetative fragments and rhizomes (Global Invasive Species Database 2005), the long-term durability of rhizomes under cold conditions (Sytsma and Anderson 1993a) and its high desiccation tolerance (Barnes *et al*. 2013) are notable biological characteristics that can facilitate its establishment. Vigorous growth and establishment may be curtailed in populations subjected to icy or frosty conditions as the emergent parts of the plant, at least, appear to have a low tolerance to these and can die off under such conditions (GB Non-Native Species Secretariat 2011). Having said that, “the question of low temperature limitation has not been adequately

Stage 2 - Detailed assessment: Section B – Establishment

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N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				addressed" (GB Non-Native Species Secretariat 2011). Nevertheless, *Myriophyllum aquaticum* appears to have a wide tolerance to pH, moderately cold to warm water temperatures and water hardness (refer to response to Questions 2.02 and 2.03) which may facilitate establishment under varying abiotic conditions in suitable habitats. Further to this, *Myriophyllum aquaticum* has been demonstrated to have a high phenotypic plasticity in response to varying ambient CO_2, light and temperature conditions, which is largely dependent on carbon availability (dissolved inorganic carbon) over light and temperature. This high phenotypic plasticity might contribute to the success and invasiveness of *Myriophyllum aquaticum* in a wide range of aquatic habitats (Eusebio Malheiro *et al*. 2013). *Myriophyllum aquaticum* is well adapted to survive both drawdown and flooding events of varying duration through its amphibious morphological character (reviewed in Wersal and Madson 2011a). The plant has been observed in England to survive in a terrestrial form when ponds dry out (Centre for Ecology and Hydrology 2004).
2.11	How likely is it that the organism's capacity to spread will facilitate its establishment?	LIKELY	HIGH	Within systems, internal spread by natural means is common, principally occurring *via* vegetative fragmentation that is induced naturally or by human-related disturbance and through the dispersal of rhizomes (Global Invasive Species Database 2005; CABI 2007). Between watersheds, there is a very low potential for natural spread, although it could be transferred *via* plant fragments attached to large water fowl (CABI 2007; GB Non-Native Species Secretariat 2011). Anthropogenic-mediated transfer is the principal pathway to facilitate the establishment of the plant from colonised to uncolonised waters (CABI 2007; GB Non-Native Species Secretariat 2011). Free-floating plant fragments of *Myriophyllum aquaticum* with adventitious roots have the ability to uptake nutrients (i.e. Nitrogen and Phosphorus) directly from the water column, which may enhance their survival and facilitate their long-distance dispersal capacity (Sytsma and Anderson 1993b; Wersal and Madson 2011b).

Stage 2 - Detailed assessment: Section B – Establishment

This section evaluates the probability of establishment of an organism within Ireland. For organisms which are already well established in Ireland there is no need to complete this section - move straight to the Spread section.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
2.12	How likely is it that the organism's adaptability will facilitate its establishment?	LIKELY	HIGH	As stated previously, *Myriophyllum aquaticum* can establish in a wide range of freshwater habitats (i.e. slow-moving or static waters including lakes, reservoirs, ponds, slow-flowing rivers [notably in their back waters], canals, fens, ditches and irrigation channels). It is particularly suited to eutrophic conditions and has some tolerance to brackish water (Centre for Ecology and Hydrology 2004; CABI 2007; GB Non-Native Species Secretariat 2011). Refer to response to Question 2.10 for details on adaptable biological traits of the plant which may also facilitate its establishment.
2.13	How likely is it that the organism could establish despite low genetic diversity in the founder population?	VERY LIKELY	MEDIUM	Although reproduction is likely solely asexual in Ireland, there is presently no evidence to suggest low genetic diversity in the founder population will inhibit any future establishment. It is also probable that genetic diversity is assured as this species has been introduced from a range of different importers and potentially from a variety of different locations – suggesting a potentially broad genetic diversity (although there is no proof of this). Indeed, many other non-native aquatic plants have established robust populations in Ireland in spite of apparent low genetic diversity in their founder populations.
2.14	Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Ireland? If possible, specify the instances of invasion elsewhere in the justification box	VERY LIKELY	VERY HIGH	It has already demonstrated this capacity in Ireland.
2.15	If the organism does not establish, then how likely is it that transient populations will continue to occur?	N/A		
2.16	Estimate the overall likelihood of establishment. Mention any key issues in the comments box	VERY LIKELY	VERY HIGH	*Myriophyllum aquaticum* is already established in Ireland. Refer to responses to previous questions in this section for further details.

Stage 2 - Detailed assessment: Section C - Spread

This section evaluates the probability of spread of an organism within Ireland. Spread is defined as the expansion of the geographical distribution of an organism within the risk assessment area.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
3.01	What area (given in % or 10km squares) in Ireland could the organism establish (0% - 10%, 11% - 33%, 34% - 67%, 68% - 90% or 91% - 100%)?	11% - 33% (of 10 km squares)	HIGH	As stated previously, *Myriophyllum aquaticum* can establish in a wide range of freshwater habitats (i.e. slow-moving or static waters including lakes, reservoirs, ponds, slow-flowing rivers [notably in their back waters], canals, fens, ditches and irrigation channels). These are abundance in Ireland. It is particularly suited to eutrophic conditions and has some tolerance to brackish water (Centre for Ecology and Hydrology 2004; CABI 2007; GB Non-Native Species Secretariat 2011).
3.02	How important is the expected spread of this organism in Ireland by natural means (minimal, minor, moderate, major or massive)?	MODERATE	HIGH	Within systems, internal spread by natural means is common, principally occurring *via* vegetative fragmentation induced naturally or by human-related disturbance and through the dispersal of rhizomes (Global Invasive Species Database 2005; CABI 2007). Between watersheds, there is a very low potential for natural spread, although it could be transferred *via* plant fragments attached to large water fowl (CABI 2007; GB Non-Native Species Secretariat 2011).
3.03	How important is the expected spread of this organism in Ireland by human assistance (minimal, minor, moderate, major or massive)?	MODERATE	HIGH	Anthropogenic-mediated transfer is the principal pathway to facilitate the establishment of the plant from colonised to uncolonised waters (CABI 2007; GB Non-Native Species Secretariat 2011). According to GB Non-Native Species Secretariat (2011), "Deliberate planting in garden ponds and deliberate / accidental transfer to the wild aids rapid spread within the country, increasing the risk of escape to natural areas." The movement of boats, angling gear and other water sports equipment has a high potential to inadvertently spread *Myriophyllum aquaticum* within and between watersheds. However, at present, the risk of spread *via* this pathway is low as the current distribution of the plant in Ireland is relatively restricted, being principally confined to isolated ponds (Kelly and Maguire 2009; National Biodiversity Data Centre 2009).
3.04	Within Ireland, how difficult would it be to contain the organism (minimal, minor, moderate, major or massive)?	MODERATE	HIGH	As the current distribution of the plant in Ireland is relatively restricted (Kelly and Maguire 2009; National Biodiversity Data Centre 2009), containment is feasible in many instances. However, in practice this requires a multi-faceted approach, including the implementation of local eradication programmes, stakeholder education and awareness, biosecurity measures and the implementation of legislation (i.e. Regulations 49 and 50 of European Communities (Birds and Natural Habitats) Regulations 2011, SI 477/2011) to prevent further spread.

Stage 2 - Detailed assessment: Section C - Spread

This section evaluates the probability of spread of an organism within Ireland. Spread is defined as the expansion of the geographical distribution of an organism within the risk assessment area.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				Containment of the plant in large open water systems would be difficult. However, external spread can also be mitigated through the implementation of routine biosecurity measures.
3.05	What proportion (%) of the area in Ireland suitable for establishment, if any, has already been colonised by the organism?	0% - 10%	VERY HIGH	Refer to responses to Questions 9 and 3.04.
3.06	What proportion of the area in Ireland suitable for establishment, if any, do you expect to have been invaded by the organism five years from now (including any current presence)?	0% - 10%	HIGH	The enactment and enforcement of proposed restrictions on its sale and import and the further implementation of biosecurity practices by stakeholders may mitigate for some future spread. Its potential for spread from small artificial waters where it is present is considered low as these are generally confined systems. However, based on experiences from Britain (GB Non-Native Species Secretariat 2011), and the history of spread in Ireland to date (National Biodiversity Data Centre 2009) some further spread is inevitable in the coming years. There is some uncertainty regarding the capacity for *Myriophyllum aquaticum* to establish vigorous populations throughout the island of Ireland under current climatic conditions, particularly in inland or northern areas of the country, as very cold winters may curtail growth and therefore reduce the amount of inoculum to colonise new areas.
3.07	What other timeframe would be appropriate to estimate any significant further spread of the organism (10, 20, 40, 80 or 160 years)? Please comment on why this timeframe is chosen.	10-20 years	HIGH	Some further spread to uncolonised systems or isolated waters is considered likely (Refer to Question 3.06).
3.08	In this timeframe, what proportion of the endangered area (including any currently occupied areas) is likely to have been invaded by this organism?	0% - 10%	HIGH	Refer to Questions 3.06 and 3.07.
3.09	Based on the answers to questions on the potential for establishment and spread in Ireland, define the area endangered by the organism. Be as specific as possible. If available, provide a map showing the area most likely to be	-	HIGH	11% - 33% of 10 km squares in Ireland are at risk of colonisation (refer to Question 3.01). In Britain the endangered areas most at risk are natural ponds and slow flowing rivers and canals in close proximity to areas with high population numbers. Dispersal is most likely on a local scale, and so ponds are the habitats most at risk. The question of low temperature limitation has not been adequately addressed, and although temperature

Stage 2 - Detailed assessment: Section C - Spread

This section evaluates the probability of spread of an organism within Ireland. Spread is defined as the expansion of the geographical distribution of an organism within the risk assessment area.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
	endangered.			limits growth rates in Spring (Newman, personal observation), it is likely that all ponds, slow flowing canals, backwaters in rivers and other static areas within GB will be at risk from this species." (GB Non-Native Species Secretariat 2011). This is also likely to be the case in Ireland.
3.10	Estimate the overall potential for future spread for this organism in Ireland (very slowly, slowly, moderately, rapidly or very rapidly). Use the justification box to indicate any key issues .	MODERATELY	HIGH	If restrictions on sale and import are enforced and biosecurity measures are routinely implemented, the rate of further range extensions to uncolonised systems will likely be reduced as the principal mechanism of spread is human-mediated. A warmer climate in Ireland as a result of climate change may increase the capacity for survival, establishment and spread of *Myriophyllum aquaticum* in the country (refer to Section F for more details on this). The plant was first recorded in the island of Ireland in Lough Neagh in 1984 (National Biodiversity Data Centre 2009) and since that time (30 years) has spread to 42 individual sites in the country, the majority of which are ponds in private estates or golf courses (National Biodiversity Data Centre 2009).

Stage 2 - Detailed assessment: Section D - Impact

This section evaluates the probability of impact of an organism within Ireland.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
4.01	How great is the economic loss caused by the organism within its global distribution (excluding Ireland), including the cost of any current management?	MAJOR	HIGH	There is only limited information available on the economic loss caused and management costs incurred by *Myriophyllum aquaticum* within its global distribution. According to a review by EPPO (2005), "Anderson (1993) outlines the ways in which aquatic weeds such as *M. aquaticum* can have detrimental impacts, including interference with the flow of irrigation water, transport, hydro-electric power production, fisheries, recreation, and increased risk of health hazards. Some specific problems reported for *M. aquaticum* include interference with fisheries in South Africa (Jacot-Guillarmod, 1977), major problems for hydroelectric power production and forestry development in Argentina (Fernandez *et al*. 1993) and increased incidence of mosquitoes in California (Anderson, 1993). *M. aquaticum* is a particular problem in irrigation channel and river systems, being one of the two most important aquatic weeds at 39% of sites surveyed in the Sorraia river system in Portugal. In California it had infested 24% of irrigation channel systems, with 914 km of waterway affected by 1985. Direct control costs are approximately Euro 200,000 over a 2-year period, with total annual expenditure on aquatic weed control in the western USA estimated to be up to Euro 50 million (Anderson, 1993)." In Britain, significant direct costs can be incurred from interference with irrigation, drainage, transport, fisheries, recreation and health (GB Non-Native Species Secretariat 2011).
4.02	How great has the economic cost of the organism been in Ireland from the time of introduction to the present? Exclude any costs associated with managing the organism from your answer.	MINIMAL	VERY HIGH	There is no specific information available on the economic loss caused by *Myriophyllum aquaticum* to date in Ireland. However, it is highly likely to be minimal or non-existent to date. This is principally due to the restricted distribution of the plant in the country and the very low frequency of abundant populations where it has established.
4.03	How great is the economic cost of the organism likely to be in the future in Ireland? Exclude any costs associated with managing the organism from your answer.	MINOR to MODERATE	LOW	This is difficult to quantify and will depend on the future spread of the plant in Ireland coupled with an ability to establish abundant populations. There may be financial implications if conservation goals such as those specified in the EC Habitats Directive and the EU Water Framework Directive come under threat. For British populations of *Myriophyllum aquaticum*, according to GB Non-Native Species Secretariat (2011), "The NAPRA economics spreadsheet

Stage 2 - Detailed assessment: Section D - Impact *This section evaluates the probability of impact of an organism within Ireland.*				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
				calculated a predicted cost of £15.4 million [GBP] over 25 years for eradication and control costs over the whole of GB. Not all sites would be controlled as private areas would be exempt from any control programme."
4.04	How great have the economic costs of managing this organism been in Ireland from the time of introduction to the present?	MINOR	VERY HIGH	There is no specific information available on this. However, it is highly likely to be minimal to date. This is principally due to the restricted distribution of the plant in the country and the very low frequency of abundant populations where it has established. Small costs have been incurred from conducting specific habitat surveys, and the creation of identification and awareness literature by Inland Fisheries Ireland, its predecessors and others. The development of a specific Action Plan for *Myriophyllum aquaticum* by Invasive Species Ireland and their partners has also incurred some minor costs (Kelly and Maguire 2009).
4.05	How great is the economic cost of managing this organism likely to be in the future in Ireland?	MINOR to MODERATE	LOW	This is difficult to quantify and will depend on the future spread of *Myriophyllum aquaticum* in Ireland coupled with an ability to establish abundant populations.
4.06	How important is environmental harm caused by the organism within its global distribution?	MODERATE to MAJOR	VERY HIGH	According to a review by GB Non-Native Species Secretariat (2011) on environmental harm caused by *Myriophyllum aquaticum* within its global distribution, "It is a problem weed in its native South America (Fernandez *et al*. 1993) and is aggressively spreading in Southern Africa, South East Asia, USA (Anderson 1993) and Portugal (Teles and Pinto da Silva 1975). In its native range it is listed as a weed of lakes, ponds, marshes, fens and irrigation channels in Argentina and Brazil, while in lakes and ponds only in Chile (Fernandez *et al*. 1993). Elsewhere in its range it causes significant problems, e.g. interference with fisheries in South Africa (Jacot-Guillarmod 1977), major problems for hydroelectric power production and forestry development in Argentina (Fernandez *et al*. 1993), increased incidence of mosquitoes in California (Anderson 1993) and it is one of the two most important aquatic weeds at 39% of sites surveyed in the Sorraia river system in Portugal. In California it infested 24% of irrigation channel systems with 914 km of waterway affected by 1985, with direct control costs approximately Euro 200,000 over a 2-year period (Anderson 1993). Hussner and Hilt (2009) show that the presence of neophytes, including *M. aquaticum*, cause a loss in native species in very short timescales of less than 10 years in rivers in northern Germany. No further literature was found."

Stage 2 - Detailed assessment: Section D - Impact

This section evaluates the probability of impact of an organism within Ireland.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
4.07	How important has the impact of the organism on biodiversity* been in Ireland from the time of introduction to the present? *e.g. decline in native species, changes in community structure, hybridisation	MINIMAL	HIGH	There is no specific information available on impacts of *Myriophyllum aquaticum* on biodiversity in Ireland to date. However, it is highly likely to be minimal or non-existent. This is principally due to the restricted distribution of the plant in the country and the very low frequency of abundant populations where it has established. Where dense, light-excluding stands of *Myriophyllum aquaticum* occur (i.e. in large ponds in Fota Island, Co. Cork and Kilmeaden, Co. Waterford) it is likely that any native aquatic plant species present have been displaced. However, no specific investigations have been made in this regard.
4.08	How important is the impact of the organism on biodiversity likely to be in the future in Ireland?	MODERATE	LOW	This is difficult to quantify and will depend on the future spread of *Myriophyllum aquaticum* in Ireland coupled with an ability to establish abundant populations. If the plant establishes dense populations in as yet uncolonised freshwaters in Ireland, there may be implications for the classification of ecological status under the EU Water Framework Directive and the conservation status of certain species and habitats under the EU Habitats Directive. According to a general review by EPPO (2005), "While *M. aquaticum* may provide cover for some aquatic organisms, it can seriously change the physical and chemical characteristics of water bodies, and infestations alter aquatic ecosystems by shading out algae that serve as the basis of the aquatic food chain. In eutrophic coastal or brackish waters conditions it has been observed to displace native species."
4.09	How important has alteration of ecosystem function* caused by the organism been in Ireland from the time of introduction to the present? *e.g. habitat change, nutrient cycling, trophic interactions	MINIMAL	HIGH	There is no specific information available any impacts to ecosystem function caused by *Myriophyllum aquaticum* in Ireland to date. However, it is highly likely to be minimal or non-existent. This is principally due to the restricted distribution of the plant in the country and the very low frequency of abundant populations where it has established. Also refer to EPPO (2005) comment above.

Stage 2 - Detailed assessment: Section D - Impact

This section evaluates the probability of impact of an organism within Ireland.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
4.10	How important is alteration of ecosystem function caused by the organism likely to be in Ireland in the future?	MODERATE	LOW	This is difficult to quantify and will depend on the future spread of *Myriophyllum aquaticum* in Ireland coupled with an ability to establish abundant populations. If the plant establishes dense populations in as yet uncolonised freshwaters in Ireland, there may be implications for the classification of ecological status under the EU Water Framework Directive and the conservation status of certain species and habitats and under the EU Habitats Directive
4.11	How important has decline in conservation status* caused by the organism been in Ireland from the time of introduction to the present? *e.g. sites of nature conservation value, WFD classification, etc.	MINIMAL	VERY HIGH	There has been no official decline in conservation status caused by *Myriophyllum aquaticum* to date.
4.12	How important is decline in conservation status caused by the organism likely to be in the future in Ireland?	MINOR to MODERATE	LOW	As stated previously, this is difficult to quantify and will depend on the future spread of *Myriophyllum aquaticum* in Ireland coupled with an ability to establish abundant populations. If the plant establishes dense populations in as yet uncolonised freshwaters in Ireland, there may be implications for the classification of ecological status under the EU Water Framework Directive and the conservation status of certain species and habitats under the EU Habitats Directive
4.13	How important is social or human health harm (not directly included in economic and environmental categories) caused by the organism within its global distribution?	MODERATE	HIGH	Refer to response to Question 4.06.
4.14	How important is social or human health harm (not directly included in economic and environmental categories) caused by the organism within Ireland?	MINIMAL	HIGH	No such harm has been reported in Ireland to date. According to Lansdown (2011), who assessed the social or human health harm of *Myriophyllum aquaticum* in Britain, “Dense growth of parrot's feather can cause flooding and ponding of water, leading to increased health hazards, although these are not likely to be a serious problem in Great Britain. It can also have significant impacts on the aesthetic qualities of wetlands and prevent water-borne recreation.”

Stage 2 - Detailed assessment: Section D - Impact *This section evaluates the probability of impact of an organism within Ireland.*				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
4.15	How important is it that genetic traits of the organism could be carried to other organisms / species, modifying their genetic nature and making their economic, environmental or social effects more serious?	MINIMAL	VERY HIGH	Highly unlikely - there is no evidence for this.
4.16	How important is the impact of the organism as food, a host, a symbiont or a vector for other damaging organisms (e.g. diseases)?	MINIMAL	VERY HIGH	
4.17	How important might other impacts not already covered by previous questions be resulting from introduction of the organism? Specify in the justification box.	MINIMAL	HIGH	
4.18	How important are the expected impacts of the organism despite any natural control by other organisms, such as predators, parasites or pathogens that may already be present in Ireland?	MINIMAL	HIGH	*Myriophyllum aquaticum* is not naturally controlled by any predator, parasite or pathogen in Ireland.
4.19	Indicate any parts of Ireland where economic, environmental and social impacts are particularly likely to occur. Provide as much detail as possible, where possible include a map showing vulnerable areas.		MEDIUM	Many freshwaters in Ireland are vulnerable to colonisation by *Myriophyllum aquaticum*. The plant is typically found growing in slow-moving or static waters including lakes, reservoirs, ponds, slow-flowing rivers (notably in their back waters), canals, fens, ditches and irrigation channels but not suited to fast flowing waters. It is particularly suited to eutrophic conditions and has some tolerance to brackish water (Centre for Ecology and Hydrology 2004; CABI 2007; GB Non-Native Species Secretariat 2011). As stated previously, in Britain the endangered areas are considered to be most at risk are as follows, “natural ponds and slow flowing rivers and canals in close proximity to areas with high population numbers. Dispersal is most likely on a local scale, and so all ponds are the most likely at risk habitat. …. it is likely that all ponds, slow flowing canals, backwaters in rivers and other static areas within GB will be at risk from this species.” (GB Non-Native Species Secretariat 2011). This is also likely to be the case in Ireland.

Stage 2 - Detailed assessment: Section D - Impact *This section evaluates the probability of impact of an organism within Ireland.*				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
4.20	Estimate the overall potential impact of this organism in Ireland. Use the justification box to indicate any key issues.	MODERATE to MAJOR	MEDIUM	Refer to response to Question 5.01.

Stage 2 - Detailed assessment: Section E – Conclusion *This section requires the assessor to provide a score for the overall risk posed by an organism, taking into account previous answers to entry, establishment, spread and impact questions.*				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
5.01	Estimate the overall risk of this organism in Ireland (noting answers given in 1.11, 2.16, 3.10 & 4.20).	MODERATE to MAJOR	MEDIUM	*Myriophyllum aquaticum* has already demonstrated its ability to establish under natural conditions in Ireland. Its capacity to cause negative impacts in a number of countries where it has established (including Britain) has also been documented (refer to elsewhere in this risk assessment). What is uncertain is how invasive this plant may or may not become should it become established in other suitable waters in Ireland. To date, there are only two known populations in the country, where the plant could be considered invasive. Therefore, with the limited information available to inform this risk assessment and in acknowledgement of the knowledge gaps that exist, the overall risk of this organism in Ireland is presently considered to be 'moderate to major' with 'medium confidence'. One cautionary note is that, in Britain, *Myriophyllum aquaticum* can cause a range of detrimental environmental and economic impacts and this may become evident in Ireland if the plant establishes in any natural open water systems where further systemic spread can more easily occur.

Stage 2 - Detailed assessment: Section F – Additional questions

This section is used to gather information about the potential effects of climate change on the risk posed by an organism. It is also an opportunity for the risk assessor to highlight high priority research that could help improve the risk assessment.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
6.01	What aspects of climate change, if any, are most likely to affect the risk assessment for this organism?		MEDIUM	Climate change is expected to increase water temperatures over time in Ireland, with increased periods of drought in summer and higher rainfall in winter leading to more flooding events (Desmond *et al*. 2008). Some of the reviewed literature suggests that *Myriophyllum aquaticum* is better suited to thrive in a warmer climate than that experienced in Ireland (e.g. Global Invasive Species Database 2005; CABI 2007). Therefore, warmer temperatures may enhance its capacity for establishment in this country. Indeed, as stated previously, the plant has established dense, mono-specific stands in only two sites in Ireland (Fota Island, Co. Cork and Kilmeaden, Co. Waterford) (J. Caffrey, personal observation), both of which are subjected to a relatively milder climate as they are near the south coast than more inland, less vigorous populations (Met Éireann 2014). In addition, the over-wintering capability of *Myriophyllum aquaticum* may be enhanced by a warmer climate, experiencing less ice or frost damage which may result in more abundant population growth. Global climate and regional environmental niche modelling project that the suitable range for *Myriophyllum aquaticum* in the island of Ireland will increase by +12% and +44%, respectively, by 2080 (based on the International Panel on Climate Change high emissions climate change scenario) (Kelly *et al*. 2014). Further to the above, Eusebio Malheiro *et al*. (2013) demonstrated that CO_2 (as dissolved inorganic carbon) acts as the major trigger for plant growth in *Myriophyllum aquaticum*, facilitating both morphological and physiological acclimations. As virtually all climate change projections predict increased levels of atmospheric CO_2 (and thus dissolved CO_2), this may have the potential to enhance the growth of *Myriophyllum aquaticum* in future in Ireland.
6.02	What is the likely timeframe for such changes (5, 10, 15 , 20, 50 or 100 years)?	10-50 YEARS	LOW	This is based on global climate and regional environmental niche modelling projection by Kelly *et al*. (2014) as referred to above.
6.03	What aspects of the risk assessment are most likely to change as a result of climate change		MEDIUM	More abundant growth in Irish *Myriophyllum aquaticum* populations may result in the kind of environmental and economic impacts observed presently in other countries where the plant is considered invasive.

Stage 2 - Detailed assessment: Section F – Additional questions

This section is used to gather information about the potential effects of climate change on the risk posed by an organism. It is also an opportunity for the risk assessor to highlight high priority research that could help improve the risk assessment.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
6.04	If there is any research that would significantly strengthen confidence in the risk assessment, please note this here. If more than one research area is provided, please list in order of priority.	YES		In general, there is a paucity of information available to assess the invasive potential of *Myriophyllum aquaticum* in Ireland. Such information would significantly strengthen this risk assessment. Information from Irish gardeners or stockists who have first-hand knowledge of its growth, reproduction and general suitability to the Irish climate may also be useful in this regard. It would be useful to determine the present status of the plant at all locations where it is present. More detailed information on the status of the plant in Britain would also contribute to the assessment because of the similarity in climate between the two countries.

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