Risk Assessment of *Azolla filiculoides*

Name of Organism:	*Azolla filiculoides* - Water Fern
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

Stage 1 - Organism Information

Stage 2 - Detailed Assessment
Section A - Entry
Section B - Establishment
Section C - Spread
Section D - Impact
Section E - Conclusion
Section F - Additional Questions

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

Name of Document:	Risk Assessment of *Azolla filiculoides*				
Author (s):	Dr Michael Millane and Dr Joe Caffrey				
Authorised Officer:	Dr Joe Caffrey				
Description of Content:	Non-native species risk assessment				
Approved by:	Dr Cathal Gallagher				
Date of Approval:	15/09/2014				
Assigned review period:	n/a				
Date of next review:	n/a				
Document Code	n/a				
This documents comprises	TOC	Text	List of tables	List of Figures	No. Appendices
	n/a	YES	n/a	n/a	0

Version Control Table

Version No.	Status	Authors(s)	Reviewed by	Approved by	Date of issue
Draft 1	Complete	Dr Michael Millane	Dr Joe Caffrey	-	20/01/2014
Expert review	Complete	Dr Michael Millane	Dr Jonathan Newman	-	02/03/2014
Public Consultation 1	Complete	Dr Michael Millane	Dr Joe Caffrey	-	09/05/2014
Public Consultation 2	Complete	Dr Michael Millane	Dr Joe Caffrey		14/08/2014
Final	Complete	Dr Michael Millane	Dr Joe Caffrey	Dr Cathal Gallagher	15/09/2014

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	*Azolla filiculoides* Lamarck, *Azolla rubra* R.Br., *Azolla japonica* Franch. & Sav., *Azolla arbuscula* Desv., *Azolla filiculoides var. rubra* Lam. (R.Br.) Strasb., *Azolla magellanica* Wild., *Azolla squamosa* Molina; *Azolla*, large mosquito fern, mosquito fern, Pacific Azolla, red Azolla, red-water fern, water velvet and water fern (reviewed in Hussner 2010; USDA, ARS 2013).
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.		*Azolla filiculoides* is a heterosporous, floating fern up to 2.5 cm in diameter. The plants are dark green to reddish and float on the water surface, either individually or in mats, which can reach a thickness of up to 20 cm. Individual plants consist of two-lobed leaves and rhizomes. The lower lobes of the leaves are usually larger than the upper (reviewed in Hussner 2010).
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 identified *Azolla filiculoides* as one of the thirteen "most significant invasive plants in Ireland" and the latter assessment designed the plant as a 'high risk' invasive species.
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 4).
7	Where is the organism native?		Central America (Costa Rica; Guatemala; Honduras; Nicaragua); North America (western Canada; western United States, and Mexico); Hawaii; and South America (Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador; Paraguay, Peru and Venezuela) (reviewed in USDA, ARS 2013). There is evidence in West (1953) that this species was widespread in Europe before the last glaciation period, also that *Azolla* was extensive in circumpolar regions of the Arctic some 50 million years ago in the Eocene. This gives some credence to the claim that *Azolla* is native. The predominance of this species in Northern Europe may be a direct response to climate change (J. Newman pers. comm.).

Stage 1 - Organism Information *The aim of this section is to gather basic information about the organism.*			
N	**QUESTION**	**RESPONSE**	**COMMENT**
8	What is the current global distribution of the organism (excluding Ireland)?		In addition to the countries listed in Question 7, the species is naturalised and / or invasive in western, central and southern Europe (Lumpkin and Plucknett 1980). It was originally introduced to Europe *via* France in 1880 (Marsh 1914 as cited in West 1953) but it may have been present in Europe before dying out during the last ice age (West 1953). The plant is also reported to be invasive in Africa (Kenya, Tanzania, South Africa and Uganda [BioNET-EAFRINET 2013]), Australia, China, Japan and New Zealand (Lumpkin and Plucknett, 1980).
9	What is the current distribution of the organism in Ireland?		It is recorded in 38 10km squares in Ireland (National Invasive Species Database 2013). Small isolated populations have likely been under-reported, such as those present around emergent marginal vegetation where they can be inconspicuous (Baars and Caffrey 2008).
10	Is the organism known to be invasive anywhere in the world?	YES	Refer to Question 8.

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	Ornamental 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. Ornamental and aquarium trade 2. Boating 3. Angling		*Azolla filiculoides* is imported into Ireland *via* the ornamental and aquarium sectors for sale to the public in garden centres and 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 – Ornamental 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	*Azolla filiculoides* is deliberately imported for trade. It has also been frequently found as a contaminant with other traded aquatic plants in Britain (GB Non-Native Species Secretariat 2011).
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?	VERY LIKELY	VERY HIGH	*Azolla filiculoides* is deliberately imported for trade and subsequently sold in outlets in Ireland as an oxygenator / ornamental plant for artificial watercourses, garden ponds and aquaria.
1.05	How likely is the organism to enter Ireland undetected or without the knowledge of relevant competent authorities?	VERY LIKELY	HIGH	Awareness by the relevant competent authorities at points of entry to recognise and identify this species is limited or non-existent at present. Additionally, the plant is small and often inconspicuous amongst other imported consignments.
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 or present as a contaminant of trade, survival is considered very likely. Plants remain viable under moist conditions, which is likely with aquatic plant sales. Sporocarps (i.e. spore-producing tissues) can remain viable in water for up to 3 years (Janes *et al*. 1998).

Pathway 1 – Ornamental 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, *Azolla filiculoides* is capable of growing throughout the year and is only killed by very harsh winters (Janes, 1998). In Ireland, maximum growth occurs during the warm summer months. However, there is no known seasonal restriction to inhibit the establishment of this organism from viable plant material. Trade imports and purchases may occur throughout the year.
1.08	How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	VERY LIKELY	VERY HIGH	Ireland has a high density and abundance of natural freshwaters which are suitable for the establishment of this organism as it has a wide tolerance of environmental conditions. The plant is best suited to slow-flowing or static waters in low-lying areas. This may include canals, lakes, slow-flowing rivers or the backwaters or margins of fast flowing rivers or streams (Hussner 2010). Once planted out by a purchaser, there is a risk of external spread to receptive waters *via* natural means such as waterfowl movements, water flow, if not planted in a confined system, or flooding events, if proximal to other waters.
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				
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	HIGH	The overland / cross-channel movement of boats, boat trailers and boat engines 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. The transport of spores is also a possibility *via* this route
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?	MODERATELY LIKELY	HIGH	In the absence of implementing appropriate biosecurity measures or border checks, there is an increased potential for the inadvertent spread of viable plant material and/or spores overland or cross-channel on boating equipment from infested to uninfested waters.

Pathway 2 - Boating				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
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?	LIKELY	HIGH	Provided *Azolla filiculoides* remains moist during transit and because of its small size, it is likely to survive during passage along this pathway. Spores will survive prolonged periods of desiccation and transport.
1.07	How likely is the organism to arrive during the months of the year appropriate for establishment?	LIKELY	HIGH	In Britain, *Azolla filiculoides* is capable of growing throughout the year and is only killed by very harsh winters (Janes 1998). In Ireland, maximum growth occurs during the warm summer months. However, there is no known seasonal restriction to inhibit the establishment of this organism from viable plant material. Trade imports and purchases may occur throughout the 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	Ireland has a high density and abundance of natural freshwaters which are suitable for the establishment of this organism as it has a wide tolerance of environmental conditions. The plant is best suited to slow-flowing or static waters in low-lying areas. This may include canals, lakes, slow-flowing rivers or the backwaters or margins of fast flowing rivers or streams (Hussner 2010). Transfer is ultimately dependent on environmental conditions and duration of transport, but survival for extended periods of time in moist conditions is likely (Refer to Question 1.06).
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 boats from an infested water abroad to an uninfested water in the jurisdictions. As *Azolla filiculoides* is widespread throughout much of England and parts of Wales, (GB Non-Native Species Secretariat 2011), it is considered moderately likely that the organism can enter *via* this pathway. However, it should be noted that there is no specific information available on the movement of boats from infested areas abroad into Ireland.
1.10	Do other pathways need to be considered?	YES		

Pathway 3 - Angling				
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	HIGH	The overland or cross-channel movement of angling equipment (e.g. landing or keep net, stink bag, angling box and stand, boots, waders and live bait) from an infested to uninfested area has the potential to inadvertently spread this organism if viable plant material is attached.
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?	MODERATELY LIKELY	HIGH	In the absence of implementing appropriate biosecurity measures and border checks, there is an increased potential for the inadvertent spread of viable plant material and/or spores overland or cross-channel on angling equipment from infested to uninfested waters.
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?	MODERATELY LIKELY	HIGH	Provided *Azolla filiculoides* remains moist during transit and because of its small size, it is likely to survive during passage along this pathway.
1.07	How likely is the organism to arrive during the months of the year appropriate for establishment?	LIKELY	HIGH	In Britain, *Azolla filiculoides* is capable of growing throughout the year and is only killed by very harsh winters (Janes, 1998). In Ireland, maximum growth occurs during the warm summer months. However, there is no known seasonal restriction to inhibit the establishment of this organism from viable plant material. Trade imports and purchases may occur throughout the year.
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 which are suitable for the establishment of this organism as it has a wide tolerance of environmental conditions. The plant is best suited to slow-flowing or static waters in low-lying areas. This may include canals, lakes, slow-flowing rivers or the backwaters or margins of fast flowing rivers or streams (Hussner 2010). Transfer is ultimately dependent on environmental conditions and duration of transport, but survival for extended periods of time in moist conditions is likely (Refer to Question 1.06). As the plant is often present in the wetted riparian zone of colonised freshwaters, there is a heightened risk of plant material coming in direct contact with angling gear, notably keep nets, waders and lures facilitating direct transfer through the pathway.

Pathway 3 - Angling				
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 angling equipment from an infested water abroad to an uninfested water in Ireland. As *Azolla filiculoides* is widespread throughout much of England and parts of Wales (GB Non-Native Species Secretariat 2011), it is considered moderately likely that the organism can enter *via* this pathway. As there is a paucity of specific information available on the movement of anglers from infested areas to Ireland and Northern Ireland, it is considered moderately likely that the organism can enter *via* this pathway.
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 ornamental and aquarium sectors. The movement of boats and anglers from infested areas abroad to Ireland may also facilitate entry.

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')	YES	VERY HIGH	It is recorded in a total of 38 10km squares (National Invasive Species Database 2013).
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	*Azolla filiculoides* has already demonstrated its ability to establish in Ireland. Climatic conditions in Ireland are well within the known tolerance ranges for its survival and establishment (Lumpkin and Plucknett 1980; Janes *et al*. 1998).
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	There are likely no overriding abiotic factors present to limit its further establishment in Ireland.
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	Ireland has a high density and abundance of natural freshwaters which are suitable for the establishment of this organism, as it has a wide tolerance of environmental conditions.
2.05	How likely is it that establishment will occur despite competition from existing species in Ireland?	LIKELY	HIGH	Experience from infested locations in Ireland demonstrates that *Azolla filiculoides* can out-compete and extirpate native submerged plant species. However, the plant is subject to periodic control by a naturally occurring non-native biological agent, a frond-feeding weevil *Stenopelmus rufinasus* (Baars and Caffrey 2008).
2.06	How likely is it that establishment will occur despite predators, parasites or pathogens already present in Ireland?	LIKELY	HIGH	Refer to Question 2.05.
2.07	How likely is it that establishment will occur despite existing management practices?	MODERATELY LIKELY	HIGH	In general, the state management of waterways is undertaken cognisant of ensuring biosecurity measures are in place to mitigate for the spread of aquatic invasive species. An increase in awareness by some private entities of the threat from aquatic invasive species has also reduced this risk. However, the inconspicuous character of *Azolla filiculoides* at low densities or as contaminant makes it more challenging to limit its spread and subsequent establishment over larger invasive plant species.

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
2.08	How likely is it that management practices in Ireland will facilitate the establishment of the organism?	UNLIKELY	HIGH	Refer 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	Anthropogenic control of infestations is unlikely to be achieved due to the ability of the plant to regenerate from vegetative fragments, the persistence of viable sporocarps in the local environment and the inconspicuous character of individual plants, particularly at low densities. As stated previously, the plant is subject to periodic control by a naturally occurring non-native biological agent (Baars and Caffrey 2008).
2.10	How likely is it that the biological characteristics of the organism will facilitate its establishment?	VERY LIKELY	VERY HIGH	Refer to Question 2.09 above.
2.11	How likely is it that the organism's capacity to spread will facilitate its establishment?	VERY LIKELY	VERY HIGH	As *Azolla filiculoides* is a small, free-floating aquatic plant and its sporocarps can remain viable for up to three years (Janes *et al*. 1998), it has a high potential for abiotic (e.g. through water flow and flooding events), animal (e.g. *via* waterfowl) and human-mediated spread.
2.12	How likely is it that the organism's adaptability will facilitate its establishment?	VERY LIKELY	VERY HIGH	*Azolla filiculoides* has a wide ecological tolerance which allows it to establish populations in many freshwater environments in Ireland. The plant is best suited to slow-flowing or static waters in low-lying areas. This may include canals, lakes, slow-flowing rivers or the backwaters or margins of fast flowing rivers or streams (Hussner 2010). Janes (1998) reported that the plant may have adapted to the British climate since its introduction.
2.13	How likely is it that the organism could establish despite low genetic diversity in the founder population?	VERY LIKELY	VERY HIGH	There is no evidence to suggest low genetic diversity in the founder population will inhibit any future establishment.
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?	VERY LIKELY	HIGH	Transient populations of *Azolla filiculoides* intermittently occur. However their disappearance is likely a consequence of natural biological control by *Stenopelmus rufinasus* (Baars and Caffrey 2008).

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
2.16	Estimate the overall likelihood of establishment. Mention any key issues in the comments box	VERY LIKELY	VERY HIGH	Refer to Questions 2.04, 2.09 and 2.12.

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%)?	68% - 90% of 10 km squares	HIGH	*Azolla filiculoides* has a wide ecological tolerance which allows it to establish populations in many freshwater environments in Ireland. The plant is best suited to slow-flowing or static waters in low-lying areas. This may include canals, lakes, slow-flowing rivers or the backwaters or margins of fast flowing rivers or streams (Hussner 2010). In addition, it has a high potential for spread (refer to Questions 2.07 and 2.11).
3.02	How important is the expected spread of this organism in Ireland by natural means (minimal, minor, moderate, major or massive)?	MASSIVE	VERY HIGH	Refer to Question 2.07 and 2.11.
3.03	How important is the expected spread of this organism in Ireland by human assistance (minimal, minor, moderate, major or massive)?	MASSIVE	VERY HIGH	As *Azolla filiculoides* continues to be deliberately traded, this greatly increases its potential for spread. The movement of boats and angling gear also has the potential to inadvertently spread *Azolla filiculoides* within and between watersheds (refer to Pathways 1, 2 and 3).
3.04	Within Ireland, how difficult would it be to contain the organism (minimal, minor, moderate, major or massive)?	MAJOR	HIGH	*Azolla filiculoides* currently is recorded in 38 10km squares (National Invasive Species Database 2013). Small isolated populations have likely been under reported, such as those present around emergent marginal vegetation where they can be inconspicuous (Baars and Caffrey 2008). The plant has a high potential for natural and human-mediated spread. Therefore, containment is difficult but the further establishment of the species can be slowed if routine biosecurity measures are implemented and proposed restrictions on its importation and sale are enforced. Further to this, the presence of the naturally occurring biocontrol agent *Stenopelmus rufinasus* can locally control isolated infestations (Baars and Caffrey 2008).
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 Question 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 presence of the naturally occurring biocontrol agent *Stenopelmus rufinasus* supressing some existing infestations (Baars and Caffrey 2008) and the proposed restrictions on its importation and sale under the European Communities (Birds and Natural Habitats) Regulations 2011, SI 477/2011, if enacted and enforced, should hamper future establishment.

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
3.07	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 years	HIGH	In the absence of restrictions on sale and the implementation of routine biosecurity measures, further spread is considered likely (refer to Question 3.06).
3.08	In this timeframe, what proportion of the area (including any currently occupied areas) is likely to have been invaded by this organism?	11% - 33%		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 endangered.		HIGH	Many freshwater systems (i.e. slow-flowing or static waters in low-lying areas including canals, lakes, slow-flowing rivers or the backwaters or margins of fast flowing rivers or streams) in Ireland are vulnerable to the establishment of *Azolla filiculoides.*
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 .	RAPIDLY	VERY HIGH	In the absence of restrictions on sale and the implementation of biosecurity measures by stakeholders, further range extensions may be rapid. This species is now found in just over 20% of the 10km squares mapped for Great Britain since its introduction in 1888 (GB Non-Native Species Secretariat 2011). Increasing temperature and increasing CO_2 levels favour survival and spread of this species in northern Europe, (e.g. see Brinkhuis *et al.* 2006).

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	MEDIUM	The tangible costs are difficult to accurately quantify as only limited information is available. Dense growths of *Azolla filiculoides* can impede angling and hamper the passage of boats, and require measures to be implemented to protect or restore impacted species or habitats. A survey in South Africa to gauge the problems and costs associated with *Azolla filiculoides* infestations found losses of US $589 per hectare per year in the agricultural (71%), recreational (24%) and municipal (5%) sectors. Among those most seriously affected were farmers who reported costs due to drowning of stock, replacing water pumps, setting up of alternative water supplies and the loss of recreational activities. Other reported costs were loss of property sales in housing estates adjacent to infested water bodies, labour costs to clean pump filters, loss of farming productivity and decline a in recreational fishing (McConnachie 2003 as cited in 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.	LOW / MODERATE	MEDIUM	No specific data are available regarding the economic costs of *Azolla filiculoides* in Ireland.
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.	LOW/ MODERATE	MEDIUM	This is difficult to accurately quantify (see Question 4.01 for an overview of known economic impacts likely to occur should *Azolla filiculoides* spread). Dense infestations may have socio-economic implications for boating and angling by locally reducing amenity use and for water abstraction by blocking intake pipes and water filters. It is worth noting that recreational boating is estimated to be worth €70 million to the Irish economy (Martin 2012) and the economic value of recreational angling to Ireland (including sea angling) is estimated at €755 million per annum (Inland Fisheries Ireland 2013). There may also be financial implications if conservations goals such as those specified in the EC Habitats Directive and the EU Water Framework Directive are under threat. The implementation of management and control programmes will also limit the financial impact.

Stage 2 - Detailed assessment: Section D - Impact

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

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
4.04	How great have the economic costs of managing this organism been in Ireland from the time of introduction to the present?	MINIMAL	HIGH	No specific information is available but the estimated cost of managing this organism is considered to have been minimal to date. This cost relates to the development of an action plan by Invasive Species Ireland (Kelly and Maguire 2009) and surveying for this species by Inland Fisheries Ireland, its predecessors, other agencies and individual researchers.
4.05	How great is the economic cost of managing this organism likely to be in the future in Ireland?	MAJOR	HIGH	The projected annual costs to manage *Azolla filiculoides* are difficult to quantify and depend on the magnitude of future infestations. Those which threaten aquatic habitats and species may incur control and habitat remediation costs. There may also be costs associated with clearing infested waterways for recreation purposes (e.g. boating and angling) and minimising the impact to water abstraction infrastructure in such waters.
4.06	How important is environmental harm caused by the organism within its global distribution?	MAJOR	VERY HIGH	*Azolla filiculoides* frequently builds up into thick layers or mats that completely cover the surface of ponds lakes and canals. In South Africa, mats can reach depths of 5-20cm on dams and cover areas of up to 10 ha (McConnachie *et al.* 2004). In Zimbabwe the weed has had a deleterious effect on the biodiversity of the aquatic ecosystem, resulting in a significant reduction in the number of invertebrate families recorded beneath the mat (Gratwicke and Marshal 2001). Changes in the physico-chemistry of the water beneath mats, including a reduction in dissolved oxygen, increase in carbon dioxide and a reduction in pH, have been linked to the decrease in invertebrate diversity (reviewed in GB Non-Native Species Secretariat 2011).
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.	MINOR	HIGH	There is a paucity of specific studies undertaken in this regard to date. Nationwide, this is considered 'minor'. However, where dense infestations are present this could be re-classified as 'major'. When floating mats of *Azolla filiculoides* form on the water surface, these have been observed to extirpate the underlying native plant communities by obstructing sunlight from entering the freshwater habitat (Baars and Caffrey 2008). As evident in other countries (refer to Question 4.06), these mats are also likely to inhibit gaseous exchange between the air-water interface, all of which are likely to have detrimental consequences for any aquatic fauna present (reviewed in GB Non-Native Species Secretariat 2011).

Stage 2 - Detailed assessment: Section D - Impact

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

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
4.08	How important is the impact of the organism on biodiversity likely to be in the future in Ireland?	MODERATE	HIGH	This is dependent on the magnitude of future infestations but localised impacts mentioned in relation Questions 4.06 and 4.07 are likely in infested sites.
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	MINOR	HIGH	Refer to Questions 4.06 and 4.07.
4.10	How important is alteration of ecosystem function caused by the organism likely to be in Ireland in the future?	MODERATE	HIGH	This is dependent on the magnitude of future infestations but localised impacts mentioned in relation Questions 4.06 and 4.07 are likely in infested sites.
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	HIGH	There has been no decline in conservation status reported to date.
4.12	How important is decline in conservation status caused by the organism likely to be in the future in Ireland?	MODERATE	HIGH	There is a strong likelihood based on known impacts in other jurisdictions that future invasions of *Azolla filiculoides* will result in localised detrimental impacts to native habitats and species in Ireland. Depending on the magnitude of infestation, these may have implications for Natura 2000 or Water Framework Directive sites. *Stenopelmus rufinasus* may mitigate these impacts.
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	MEDIUM	Dense infestations are a danger to children and pets who may attempt to walk onto vegetated water surfaces without appreciating that there is deep water underneath (GB Non-Native Species Secretariat 2011).
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	MEDIUM	None reported.

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. Although *Azolla filiculoides* is known to hybridise with other *Azolla* spp. (Van Cat *et al.*1989 as cited in GB Non-Native Species Secretariat 2011), it is believed to be the only *Azolla* sp. present in the wild in Ireland.
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	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?	MODERATE	HIGH	As mentioned previously, *Azolla filiculoides* is periodically subject to control by a naturally occurring, non-native biological agent, *Stenopelmus rufinasus* (Baars and Caffrey 2008). However, no information is available to ascertain the overall level of control provided by this species in Ireland and its capacity to affect widespread control in future.
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.		HIGH	*Azolla filiculoides* has a wide ecological tolerance which allows it to establish populations in many freshwater environments in Ireland. The plant is best suited to slow-flowing or static waters in low-lying areas. This may include canals, lakes, slow-flowing rivers or the backwaters or margins of fast flowing rivers or streams (Hussner 2010). In addition, it has a high potential for spread (refer to Questions 2.07 and 2.11). Greater impacts are likely to occur in smaller lakes (or sheltered bays in larger lakes), ponds, slow-flowing or static systems where dense floating mats are more likely to develop.
4.20	Estimate the overall potential impact of this organism in Ireland. Use the justification box to indicate any key issues.	MODERATE / MAJOR	VERY HIGH	Its wide environmental tolerance and high ability to establish and spread indicate that this species has the potential to cause localised ecological, environmental and socio-economic impacts should it become established in other natural freshwaters in Ireland. Small lakes (or sheltered bays in larger lakes) ponds, slow-flowing or static systems where dense floating mats are more likely to develop are particularly vulnerable. *Stenopelmus rufinasus* may offer a degree of natural control.

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 / MAJOR	VERY HIGH	This non-native species poses a moderate to major risk to native biodiversity, native ecosystems and conservation goals as well as having the potential to cause negative socio-economic impacts in slow-flowing or still waters due to its capacity to spread rapidly and establish dense infestations. The presence of *Stenopelmus rufinasus* may offer a degree of natural control.

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?		LOW	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). As the optimum temperature for both nitrogen fixation and oxygen evolution for *Azolla filiculoides* is 25°C (Wong *et al*. 1987), the range of *Azolla filiculoides* could be expected to expand in Ireland. In Britain the plant is confined to low-lying areas < 450 m above sea level (GB Non-Native Species Secretariat 2011), likely restricted by temperature. A warmer climate could lessen this restriction. Increasing CO_2 also favours establishment and survival of this species (Brinkhuis *et al*. 2006; Speelman *et al*. 2009). Global climate and regional environmental niche modelling project that the suitable range for *Azolla filiculoides* in the island of Ireland will increase by +7% and +22%, respectively, by 2080 (based on the International Panel on Climate Change high emissions climate change scenario) (Kelly *et al*. 2014).
6.02	What is the likely timeframe for such changes (5, 10, 15 , 20, 50 or 100 years)?	50 - 100	LOW	
6.03	What aspects of the risk assessment are most likely to change as a result of climate change		LOW	The survival of the biological control agent *Stenopelmus rufinasus* may be assisted by higher winter temperatures. This may assist prolonged vegetative survival of the *Azolla* fronds and allow more generations of the weevils. This may increase the level of control achieved by the weevil, reducing the impact of *Azolla*.
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.			Research on the impacts of *Azolla filiculoides* on native fish, invertebrates and ecosystem functioning would strengthen the risk assessment.

References

Baars, J-R. and Caffrey, J.M. (2008). Invasive Species Ireland, Case Study 4, Water fern, *Azolla filiculoides* – Under biological control in Ireland http://www.invasivespeciesireland.com/files/public/Case%20Studies/Case%20Study%204%20-%20Biological%20control.pdf (accessed 20/01/2014).

BioNET-EAFRINET (2013). BioNET-EAFRINET UVIMA Project (Taxonomy for Development in East Africa). http://keys.lucidcentral.org/keys/v3/eafrinet/weeds/key/weeds/Media/Html/Azolla_filiculoides_(Red_Water_Fern).htm (accessed 20/01/2014).

Botanic Gardens (2007). Ireland's National Plant Conservation Strategy - Target 10 - Managing Invasive Alien Species. Botanic Gardens, Glasnevin, Dublin. http://www.botanicgardens.ie/gspc/targets/inspc10home.htm (accessed 20/01/2014).

Brinkhuis, H., Schouten, S., Collinson, M.E., Sluijs, A., Damsté, J.S.S., Dickens, G.R., Huber, M., Cronin, T.M., Onodera, J., Takahashi, K., Bujak, J.P., Stein, R., van der Burgh, J., Eldrett, J.S., Harding, I.C., Lotter, A.F., Sangiorgi, F., van Konijnenburg-van Cittert, H., de Leeuw, J.W., Matthiessen, J., Backman, J.U., Moran, K. and the Expedition 302 Scientists. (2006).. Episodic fresh surface waters in the early Eocene Arctic Ocean. Nature, June 1, pp. 606-609. http://www.nature.com/nature/journal/v441/n7093/abs/nature04692.html

Desmond, M., O'Brien, P. and McGovern, F. (2008). A Summary of the State of Knowledge on Climate Change Impacts for Ireland. EPA Climate Change Research Programme 2007-2013. Environmental Protection Agency, Wexford pp. 20.

GB Non-Native Species Secretariat (2011). GB non-native risk assessment scheme: *Azolla filiculoides*. Food and Environment Research Agency, UK. https://secure.fera.defra.gov.uk/nonnativespecies/

Global Invasive Species Database (2010). National Biological Information Infrastructure and IUCN/SSC, Invasive Species Specialist Group http://www.issg.org/database/species/ecology.asp?si=1517 (accessed 20/01/2014).

Gratwicke, B. and Marshall, B.E. (2001). The impact of *Azolla filiculoides* Lam. on animal biodiversity in streams in Zimbabwe. *African Journal of Ecology* 39(2):216-218.

Hussner, A. (2010): NOBANIS – Invasive Alien Species Fact Sheet – *Azolla filiculoides*. – From: Online Database of the European Network on Invasive Alien Species – NOBANIS http://www.nobanis.org/files/factsheets/Azolla_filiculoides.pdf (accessed 20/01/2014).

Janes, R. (1998). Growth and survival of *Azolla filiculoides* in Britain. 2. Sexual reproduction. *New Phytologist* 138:377-384.

Kelly, J. and Maguire, C.M. (2009). *Azolla filiculoides* Invasive Species Action Plan. Prepared for NIEA and NPWS as part of Invasive Species Ireland.

Kelly, J., O'Flynn, C. and Maguire, C. (2013). Risk analysis and prioritisation for invasive and non-native species in Ireland and Northern Ireland. A report prepared for the Northern Ireland Environment Agency and National Parks and Wildlife Service as part of Invasive Species Ireland. 59 pp.

Kelly, R., Leach, K., Cameron, A., Maggs, C.A. and Reid, N. (2014). Combining global climate and regional landscape models to improve prediction of invasion risk. *Diversity and Distributions* 1-11.

Inland Fisheries Ireland (2013). Socio-economic study of Recreational Angling in Ireland. Report prepared by Tourism Development International on behalf of Inland Fisheries Ireland. Dublin. pp. 122.

Lumpkin, T. A., Plucknett, D. L. (1980). *Azolla*: Botany, Physiology, and Use as a Green Manure. *Economic Botany* 34(2): 111-153.

Martin, J. (2012). Waterways Forward Conference, Paris, France, 7-8 November 2012.

National Invasive Species Database (2013). Distribution of *Azolla filiculoides* in Ireland. National Biodiversity Data Centre http://invasives.biodiversityireland.ie/ (accessed 20/01/2014).

Speelman , E.N., Van Kempen, M.M., Barke, J., Brinkhuis, H., Reichart, G.J., Smolders, A.J., Roelofs, J.G., Sangiori, F., de Leeuw, J.W., Lotter, A.F. and Sinninghe Damste, J.S. (2009). The Eocene Arctic *Azolla* bloom: environmental conditions, productivity and carbon drawdown. Geobiology, vol. 7(2), pp.155-170. doi: 10.1111/j.1472-4669.2009.00195.x. http://www.ncbi.nlm.nih.gov/pubmed/19323694

USDA, ARS (2013). National Genetic Resources Program. Germplasm Resources Information Network - (GRIN). National Germplasm Resources Laboratory, Beltsville, MD, USA. http://www.ars-grin.gov/cgi-bin/npgs/html/taxon.pl?400375 (accessed 20/01/2014).

Van Cat, D., Watanabe, I., Zimmerman, W.J., Lumpkin, T.A. and De Waha Baillonville, T. (1989). Sexual hybridization among *Azolla* species. *Canadian Journal of Botany* 67(12):3482-3485.

West, R.G. (1953). The occurrence of *Azolla* in British interglacial deposits. *New Phytologist* 52:267-272.

Wong Fong Sang, H.W., Vu, Van Vu, Kijne, J.W., Vu, T.T. and Planque, K. (1987). Use of *Azolla* as a test organism in a growth chamber of simple design. *Plant and Soil* 99: 219-230.