Information about GB Non-native Species Risk Assessments

The Convention on Biological Diversity (CBD) emphasises the need for a precautionary approach towards non-native species where there is often a lack of firm scientific evidence. It also strongly promotes the use of good quality risk assessment to help underpin this approach. The GB risk analysis mechanism has been developed to help facilitate such an approach in Great Britain. It complies with the CBD and reflects standards used by other schemes such as the Intergovernmental Panel on Climate Change, European Plant Protection Organisation and European Food Safety Authority to ensure good practice.

Risk assessments, along with other information, are used to help support decision making in Great Britain. They do not in themselves determine government policy.

The Non-native Species Secretariat (NNSS) manages the risk analysis process on behalf of the GB Programme Board for Non-native Species. Risk assessments are carried out by independent experts from a range of organisations. As part of the risk analysis process risk assessments are:

- Completed using a consistent risk assessment template to ensure that the full range of issues recognised in international standards are addressed.
- Drafted by an independent expert on the species and peer reviewed by a different expert.
- Approved by an independent risk analysis panel (known as the Non-native Species Risk Analysis Panel or NNRAP) only when they are satisfied the assessment is fit-for-purpose.
- Approved for publication by the GB Programme Board for Non-native Species.
- Placed on the GB Non-native Species Secretariat (NNSS) website for a three month period of public comment.
- Finalised by the risk assessor to the satisfaction of the NNRAP.

To find out more about the risk analysis mechanism go to: www.nonnativespecies.org

Common misconceptions about risk assessments

To address a number of common misconceptions about non-native species risk assessments, the following points should be noted:

- Risk assessments consider only the risks posed by a species. They do not consider the practicalities, impacts or other issues relating to the management of the species. They therefore cannot on their own be used to determine what, if any, management response should be undertaken.
- Risk assessments are about negative impacts and are not meant to consider positive impacts that may also occur. The positive impacts would be considered as part of an overall policy decision.
- Risk assessments are advisory and therefore part of the suite of information on which policy decisions are based.
- Completed risk assessments are not final and absolute. Substantive new scientific evidence may prompt a re-evaluation of the risks and/or a change of policy.

Period for comment

Draft risk assessments are available for a period of three months from the date of posting on the NNSS website*. During this time stakeholders are invited to comment on the scientific evidence which underpins the assessments or provide information on other relevant evidence or research that may be available. Relevant comments are collated by the NNSS and sent to the risk assessor. The assessor reviews the comments and, if necessary, amends the risk assessment. The final risk assessment is then checked and approved by the NNRAP.

*risk assessments are posted online at:
https://secure.fera.defra.gov.uk/nonnativespecies/index.cfm?sectionid=51
comments should be emailed to nnss@fera.gsi.gov.uk

GB NON-NATIVE ORGANISM RISK ASSESSMENT SCHEME

For more information visit: www.nonnativespecies.org

	Name of Organism:	***Azolla filiculoides* - Water fern**
	Objectives:	To assess the risks associated with this species in GB
	Draft:	FINAL 21/03/11

N	QUESTION	RESPONSE	COMMENT
1	What is the reason for performing the Risk Assessment?		Request made by GB Programme Board
2	What is the Risk Assessment area?	GB	
3	Does a relevant earlier Risk Assessment exist?	NO OR UNKNOWN (Go to 5)	
4	If there is an earlier Risk Assessment is it still entirely valid, or only partly valid?		
A	**Stage 2: Organism Risk Assessment SECTION A: Organism Screening**		
5	Identify the Organism. Is the organism clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?	YES (Give the full name & Go to 7)	Azolla filiculoides Lamarck (Azollaceae). Azolla, water velvet, mosquito ferns, mosquito fern, water ferns, red water fern, fairy fern. Order: Hydropteridales, Kingdom: Plantae. Azolla filiculoides is most likely the only species of Azolla found in the UK. There are a number of observations in the literature referring to A. caroliniana, Willd occurring in the UK, however, no herbarium specimens are available for confirmation. Clapham et al., (1962) concludes that there is insufficient evidence for the inclusion of A. caroliniana in the flora of the British Isles and indeed this species is not included in recent floristic guides of the British Isles (Stace, 1997; Preston et al., 2002).
6	If not a single taxonomic entity, can it be redefined?		
7	Is the organism in its present range known to be invasive, i.e. to threaten species, habitats or ecosystems?	YES (Go to 9)	The species is known to be naturalized in west, central and southern Europe and is reported to be invasive in Belgium, Bulgaria, Czechoslovakia, France, Germany, Greece, Ireland, Netherlands, Spain, Hungary, Italy, Portugal, Romania, Yugoslavia and Sardinia (Lumpkin and Plucknett, 1980). The plant is also reported to be invasive in South Africa, Australia, China, Japan and New Zealand (Lumpkin and Plucknett, 1980). Even in its native range of southern South America, through western North America (including Alaska) it is described as a weed, but its negative impacts have not been quantified (Lejeune *et al* ., 1999).
8	Does the organism have intrinsic attributes that indicate that it could be invasive, i.e. threaten species, habitats or ecosystems?	YES or UNCERTAIN (Go to 9)	
9	Does the organism occur outside effective containment in the Risk Assessment area?	YES (Go to 10)	*Azolla filiculoides* was introduced into mainland Britain via Europe in 1888 (Moon, 1974). It has become naturalised in ponds canals, lakes and dykes and other slow moving fresh water (Preston and Croft, 1997; Stace, 1997).
10	Is the organism widely distributed in the Risk Assessment area?	YES & Future conditions/management procedures/policies are being considered (Go to 19)	The data from the 1987-99 survey for the New Atlas of the Flora of Britain and Ireland indicates that this species is found in just over 20% of the 10km squares mapped for Great Britain, 21% of those for Isle of Man and 60% of those for the Channel Islands. In mainland Britain the plant is commonly found in static water bodies throughout the lowland regions of southern England and the Midlands, being absent primarily from high elevation sites (> 450m). The plant is less common in Wales being restricted to sites around the periphery of the country and absent from the mountainous central areas. The plant becomes far less abundant north of Yorkshire and is missing from areas of high ground, occurring only sporadically in lower lying regions. *Azolla* is not recorded from much of Scotland, the most northerly record being St Andrews. The plant is apparently infrequently recorded in Northern Ireland being present in only 14 of the 10 km squares used in the mapping. These sites were clustered in the east of the country around the county Armagh district.
11	Does at least one species (for herbivores, predators and parasites) or suitable habitat vital for the survival, development and multiplication of the organism occur in the Risk Assessment area, in the open, in protected conditions or both?	YES (Go to 12)	
12	Does the organism require another species for critical stages in its life cycle such as growth (e.g. root symbionts), reproduction (e.g. pollinators; egg incubators), spread (e.g. seed dispersers) and transmission, (e.g. vectors)?	YES (Go to 13)	*Azolla filiculoides* has a permanent endosymbiotic relationship with the nitrogen-fixing cyanobacteria *Anabaena azollae* and other bacteria (Lejeune *et al* ., 1999).
13	Is the other critical species identified in question 12 (or a similar species that may provide a similar function) present in the Risk Assessment area or likely to be introduced? If in doubt, then a separate assessment of the probability of introduction of this species may be needed.	YES (Go to 14)	The cyanobacterium reside in a cavity in the dorsal lobe of the leaf and are transmitted between plant generations, via vegetative fragmentation of the host, or sexually within megasporocarps (Zheng *et al.* , 2008). This said, the cyanobacteria are not essential for the growth of *Azolla spp.* as plants that have had them artificially removed, by treatment with antibiotics, continue to grow in the presence of combined nitrogen (Forni, *et al.* , 1991).

14	Does the known geographical distribution of the organism include ecoclimatic zones comparable with those of the Risk Assessment area or sufficiently similar for the organism to survive and thrive?	YES (Go to 16)	
15	Could the organism establish under protected conditions (e.g. glasshouses, aquaculture facilities, terraria, zoological gardens) in the Risk Assessment area?		
16	Has the organism entered and established viable (reproducing) populations in new areas outside its original range, either as a direct or indirect result of man's activities?	YES (Go to 17)	
17	Can the organism spread rapidly by natural means or by human assistance?	YES (Go to 18)	
18	Could the organism as such, or acting as a vector, cause economic, environmental or social harm in the Risk Assessment area?	YES OR UNCERTAIN (Go to 19)	
19	This organism could present a risk to the Risk Assessment area and a detailed risk assessment is appropriate.	Detailed Risk Assessment Appropriate GO TO SECTION B	
20	This organism is not likely to be a harmful non-native organism in the Risk Assessment area and the assessment can stop.		

B	SECTION B: Detailed assessment of an organism's probability of entry, establishment and spread and the magnitude of the economic, environmental and social consequences			
	Probability of Entry	**RESPONSE**	**UNCERTAINTY**	**COMMENT**
1.1	List the pathways that the organism could be carried on. How many relevant pathways can the organism be carried on?	many - 3	LOW - 0	Five pathways: 1) Intentional transfer and introduction by humans (e.g. plants for sale e.g. at garden centres and internet); 2) Unintentional transfer and introduction by humans (e.g. angling gear, discharge by aquarium keepers, contaminant of plant sales); 3) Natural dissemination along rivers and through movement of soil and water. Also spread on feet and feathers of birds; 4) Vegetative fragments on hulls of boats; 5) Ballast water (fresh water only).
1.2	Choose one pathway from the list of pathways selected in 1.1 to begin the pathway assessments.	Unintentional transfer associated with sale or movement of aquatic plants		The most important means of introduction into the UK is via direct sales at garden centres and aquatic specialists. Currently there are no restrictions on the importation or sale of *Azolla filiculoides* . The local spread within the UK is by natural means in water (floods) or vectored by animals and man. Assuming that direct importation was restricted then the next most important mechanism for introduction is unintentionally as a contaminant of aquatic plant sales.
1.3	How likely is the organism to be associated with the pathway at origin?	moderately likely - 2	MEDIUM -1	*Azolla filiculoides* is present throughout much of the low lying areas of the southern half of Britain, including the Isle of Man and the Channel Islands (see comments, row 18, question10). Although, it is relatively uncommon in Northern Ireland, the plant might be expected to expand its geographic range to occupy low level sites (<450 m) that have static, or slow moving water bodies. *A. filiculoides* has also been recorded within most of the central and western Europe countries (see comments row 15, question 7).
1.4	Is the concentration of the organism on the pathway at origin likely to be high?	likely - 3	MEDIUM -1	*Azolla* when present is likely to be in high numbers. Vegetative fragments of the plant can adhere to plants, or sporocarps can be present in soil or potting material.
1.5	How likely is the organism to survive existing cultivation or commercial practices?	moderately likely - 2	LOW - 0	No screening for *Azolla* is required for plants at source. Attached vegetative fragments can be detected through careful inspection. However, it is much more difficult to detect sporocarps.
1.6	How likely is the organism to survive or remain undetected by existing measures?	very likely - 4	LOW - 0	Very difficult to detect sporocarps. Detection and removal of vegetative fragments is also difficult.
1.7	How likely is the organism to survive during transport /storage?	very likely - 4	LOW - 0	*Azolla* vegetative fragments remain viable provided they are kept moist, which is likely with aquatic plant sales. Sporocarps can remain viable in soils for up to 3 years (Janes *et al* ., 1998b).
1.8	How likely is the organism to multiply/increase in prevalence during transport /storage?	moderately likely - 2	MEDIUM -1	*Azolla* is capable of rapid vegetative growth, which would take place during transportation provided it is kept moist.
1.9	What is the volume of movement along the pathway?	moderate - 2	HIGH -2	The import of aquatic plants into the UK is not well regulated and only a few controls exist. Difficult to asses what the actual volumes are and the potential for contamination.
1.10	How frequent is movement along the pathway?	often - 3	MEDIUM -1	Difficult to obtain data on how frequently contamination may occur along this pathway. A recent article in 'Gardening Which?' magazine found that *Azolla filiculoides* was growing among other plants in a quarter of the 16 garden centres surveyed in the west England.
1.11	How widely could the organism be distributed throughout the Risk Assessment area?	widely - 3	LOW - 0	The species is well established in slow moving and static water bodies throughout much of the low lying areas of the southern half of the Great Britain (see comments row 18, question 10). It is also present and locally abundant in many countries within western Europe (see comments row 15, question 7) . The species has not been widely recorded from the northern half of Britain or Northern Ireland, and is absent from much of Scotland. The plant has been expanding its geographic range over the past 70 years and was given a rate of change value of +2.76 (Preston *et al* ., 2002). The present distribution appears to be limited by the availability of suitable waterbodies located at relatively low lying altitudes (< 450m). Present distribution may be linked to temperature, particularly the low temperature tolerance of the plant. The range of the weed could be expected to expand if climate change were to influence temperatures in the UK, potentially making more sites suitable for colonisation. The relatively confined distribution of the plant within Northern Ireland might be expected to increase within the next decade to occupy suitable habitats. It should be noted that in many areas the populations of the plant fluctuate greatly year-on-year The author believes that this is mainly due to the activities of the Azolla weevil *Stenopelmus rufinasus* , which is capable of causing local extinctions. It is difficult to predict how climate change might influence the relationship between the weed and the weevil.

1.12	How likely is the organism to arrive during the months of the year most appropriate for establishment ?	moderately likely - 2	LOW - 0	*Azolla* is capable of growing the year round in the UK and is only killed off by the most severe of winters (Janes, 1998a). In the UK, maximum growth occurs during the warm summer months which is when most pond plants would be expected to be planted out. *Azolla filiculoides* is less tolerant of high temperatures than other *Azolla* species, however the lethal maximum temperature for this species was still in excess of 35℃ (Tung and Watanabe, 1983; Wong *et al*., 1987). Janes (1998a) concludes that "although temperatures of up to 30℃ will be important in det ermining total productivity, it is unlikely that for the majority of the growing season deleterious high temperature effects will be observed in Britain".
1.13	How likely is the intended use of the commodity (e.g. processing, consumption, planting, disposal of waste, by-products) or other material with which the organism is associated to aid transfer to a suitable habitat?	very likely - 4	LOW - 0	The species is transported in water and is often deposited in ideal environments for establishment e.g. ponds, lakes, ditches.
1.14	How likely is the organism to be able to transfer from the pathway to a suitable habitat?	very likely - 4	LOW - 0	The species will be directly introduced as a contaminant with other aquatic plants.

	Probability of Establishment	RESPONSE	UNCERTAINTY	COMMENT
1.15	How similar are the climatic conditions that would affect establishment in the Risk Assessment area and in the area of current distribution?	similar - 3	LOW - 0	The species is native to southern south America, through western north America (including Alaska). The current temperature in western Europe is similar to the western United States, overlapping at the low end of the US range.
1.16	How similar are other abiotic factors that would affect establishment in the Risk Assessment area and in the area of present distribution?	similar - 3	LOW - 0	*A. filiculoides* is well established in the UK, although the species appears to have a northern limit to its native distribution that corresponds with the colder parts of Scotland. *Azolla* can tolerate a range of environmental conditions including; pH ranging from 3.5-10; heavy metal and salt pollution; low available nitrogen (Lumpkin and Plucknett, 1980). *Azolla* can also survive temperatures ranging from - 5℃ (Janes, 1998a) to 35℃ (Tung and Watanabe, 1983; Wong *et al* ., 1987).
1.17	How many species (for herbivores, predators and parasites) or suitable habitats vital for the survival, development and multiplication of the organism species are present in the Risk Assessment area? Specify the species or habitats and indicate the number.	many - 3	LOW - 0	*Azolla* can grow in any depth of water but is not tolerant of waves or turbulence and can be flushed away in fast flowing waters (CEH Information Sheet No. 22).
1.18	How widespread are the species (for herbivores, predators and parasites) or suitable habitats vital for the survival, development and multiplication of the organism in the Risk Assessment area?	frequent - 3	LOW - 0	The species inhabits all types of freshwater but prefers still waters.
1.19	If the organism requires another species for critical stages in its life cycle then how likely is the organism to become associated with such species in the risk assessment area?	likely - 3	LOW - 0	*Azolla* has a symbiotic relationship with the nitrogen fixing cyanobacterium, *Anabaena azollae* (see comments row 20, question 12). Naturally occurring plants free of the algae are extremely rare and it is considered unlikely that casual infection from the water occurs. Instead, algal inocula are transferred during the various stages of sexual reproduction (see comments row 21, question 13). Algae free plants can survive and are characteristically more compact with more roots and require nitrogen fertilizer (Peters, 1976; Ashton and Walmsley, 1976).
1.20	How likely is it that establishment will not be prevented by competition from existing species in the Risk Assessment area?	likely - 3	LOW - 0	*A. filiculoides* is often found in association with other floating aquatics such as *Lemna minuta* , *Lemna minor* , *Spirodela polyrhiza.* However, it is more competitive and frequently forms dense monospecific mats. These mats of floating plants can affect water aquatic ecosystems by eliminating submerged plants and algae (Janes, *et al* ., 1996).
1.21	How likely is it that establishment will not be prevented by natural enemies already present in the Risk Assessment area?	likely - 3	LOW - 0	In the UK *Azolla filiculoides* can be damaged by the non native weevil, *Stenopelmus rufinasus, Gyllenhal* . The weevil was first recorded on the Norfolk fens in 1921 (Jansen, 1921) and is capable of locally eliminating the weed. In addition, other invertebrates, including the aphid *Rhopalosiphum nymphaeae* and the snail *Chorebus gracilipes* , can be associated with the plant. The latter two herbivores have been recorded as causing significant damage (Rostron, 1983).
1.22	If there are differences in man's management of the environment/habitat in the Risk Assessment area from that in the area of present distribution, are they likely to aid establishment? (specify)	moderately likely - 2	HIGH -2	Variations in water management undoubtedly exist in England and Wales, however these are unlikely to differ sufficiently to make this question applicable.
1.23	How likely is it that existing control or husbandry measures will fail to prevent establishment of the organism?	very likely - 4	LOW - 0	Existing controls are not effective. The weed is actively sold in garden centres and is a frequent contaminant of aquatic plant sales.
1.24	How often has the organism been recorded in protected conditions, e.g. glasshouses, elsewhere?	N/A	MEDIUM -1	
1.25	How likely is the reproductive strategy of the organism and duration of its life cycle to aid establishment?	very likely - 4	LOW - 0	*A. filiculoides* reproduces both sexually through the production of spores and asexually via vegetative reproduction. The growth rate of *Azolla* can be extremely rapid, under favourable conditions it has a surface-area doubling time of 7-10 days (Lumpkin and Plucknett, 1982) and under laboratory conditions can double its biomass every 2.2 – 3.4 days (Kitoh *et al.,* 1993). Janes, (1998a, b) investigated the sporulation and germination of *A. filiculoides* and showed that the species sporulate regularly at many sites in Britain, most often between May and November.
1.26	How likely is it that the organism's capacity to spread will aid establishment?	very likely - 4	LOW - 0	*Azolla* is confined to the aquatic environment and is easily dispersed by vegetative fragmentation in flood waters and by bird movement . The activities of humans have undoubtedly accelerated the spread of this species.
1.27	How adaptable is the organism?	adaptable - 3	MEDIUM -1	The species inhabits all types of freshwater, but prefers still waters. *A. filiculoides* has a reasonably large range of tolerances to environmental factors such as pH, temperature, light, pollution and nutrients (Lumpkin and Plucknett, 1980).
1.28	How likely is it that low genetic diversity in the founder population of the organism will not prevent establishment?	unlikely - 1	LOW - 0	It has spread mainly by vegetative means, however has probably been repeatedly introduced via aquatic suppliers. Janes (1998b) reports that there is some evidence that *A. filiculoides* might have adapted to the British climate since its introduction.
1.29	How often has the organism entered and established in new areas outside its original range as a result of man's activities?	very many - 4	LOW - 0	*A. filiculoides* is native to the United States and subtropical America, but has been introduced into many countries including: South Africa, Australia, China, Japan, New Zealand, Europe and Latin America. Countries in Europe include: Belgium, Britain, Bulgaria, Czechoslovakia, France, Germany, Holland, Ireland, Italy, Portugal, Romania, Sardinia, Spain and Yugoslavia.

1.30	How likely is it that the organism could survive eradication campaigns in the Risk Assessment area?	very likely - 4	LOW - 0	Almost impossible to eradicate, the plant is too widespread and can over season as tiny vegetative fragments or as megasporocarps at the bottom of the water bodies.
1.31	Even if permanent establishment of the organism is unlikely, how likely is it that transient populations will be maintained in the Risk Assessment area through natural migration or entry through man's activities (including intentional release into the outdoor environment)?	likely - 3	MEDIUM -1	The species is already well established in the UK.

	Spread	RESPONSE	UNCERTAINTY	COMMENT
2.1	How rapidly is the organism liable to spread in the Risk Assessment area by natural means?	intermediate - 2	LOW - 0	Can spread along river systems in flood water and via the movement of waterfowl (Moore, 1969). The species has spread substantially since the 1962 'Atlas of the British and Irish Flora'.
2.2	How rapidly is the organism liable to spread in the Risk Assessment area by human assistance?	rapid - 3	LOW - 0	The plant is on sale in garden centres and is frequently a contaminant of aquatic plants for sale.
2.3	How difficult would it be to contain the organism within the Risk Assessment area?	difficult - 3	LOW - 0	The plant is able to regenerate from small vegetative fragments that are easily transported by birds and humans moving between water bodies. Therefore the species is likely to spread outside the RA area.
2.4	Based on the answers to questions on the potential for establishment and spread define the area endangered by the organism.		LOW - 0	Virtually all low lying areas of the southern half of the Great Britain where static or slow moving water is found are at risk (see comments row 18, question 10). The present distribution appears to be limited by the availability of suitable waterbodies located at relatively low lying altitudes (< 450m). This distribution is possibly due to the plants response to low temperatures. Janes (1998a) established that the plant was able to survive sub-zero temperatures but died after 18 hours exposure to -4 degrees centigrade. The range of the weed could be expected to expand if climate change were to influence the temperatures in the UK, potentially making more sites available for colonisation. The plant has been expanding its geographic range over the past 70 years (see row 44 Question 1.11) and was given a rate of change value of +2.76 (Preston *et al*., 2002).

	Impacts	RESPONSE	UNCERTAINTY	COMMENT
2.5	How important is economic loss caused by the organism within its existing geographic range?	moderate - 2	HIGH -2	Limited quantitative data from outside the UK. McConnachie *et al*. (2003) conducted a survey in South Africa to gauge the problems and costs associated with *Azolla* infestations. Losses of US$589 per hectare per year were reported in the following areas: agricultural (71%), recreational (24%), and municipal (5%). 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 miscellaneous costs reported were loss of property sales in housing estates bordering infested water bodies, labour costs to clean pump filters, loss of farming productivity and decline in recreational fishing.
2.6	Considering the ecological conditions in the Risk Assessment area, how serious is the direct negative economic effect of the organism, e.g. on crop yield and/or quality, livestock health and production, likely to be? (describe) in the Risk Assessment area, how serious is the direct negative economic effect of the organism, e.g. on crop yield and/or quality, likely to be?	moderate - 2	MEDIUM -1	*Azolla* has been implicated in livestock drowning, blocking of water pumps and interference with recreational use of ponds, lakes and canals. The weed can also spoil the aesthetics of ponds, lakes and water features. No data are available for the UK regarding the economic impacts of the weed. The breadth of the impact means that they are difficult to estimate, but is probably responsible for moderate to low negative economic damage.
2.7	How great a loss in producer profits is the organism likely to cause due to changes in production costs, yields, etc., in the Risk Assessment area?	moderate - 2	HIGH -2	No information.
2.8	How great a reduction in consumer demand is the organism likely to cause in the Risk Assessment area?	minor - 1	HIGH -2	A reduction in angling and recreational use is expected at sites where this nuisance species occurs.
2.9	How likely is the presence of the organism in the Risk Assessment area to cause losses in export markets?	very unlikely - 0	HIGH -2	No information available, however it is doubtful that there is a big export market for UK grown aquatic species.
2.10	How important would other economic costs resulting from introduction be? (specify)	minor - 1	HIGH -2	No information.
2.11	How important is environmental harm caused by the organism within its existing geographic range?	major - 3	LOW - 0	*A. 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 physiochemistry 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.
2.12	How important is environmental harm likely to be in the Risk Assessment area?	major - 3	LOW - 0	The environmental harm caused by *A. filiculoides* in the UK is likely to be similar to that experienced in other countries where the plant has been introduced (see comments row 75, question 2.11). The plant is already widespread on slow moving and static water bodies throughout much of the southern half of Britain. Because of the plants rapid vegetative growth, during the summer months it is frequently found forming dense floating mats of vegetation. These mats out compete other floating aquatics and cover the entire surface of the water body up to a depth of several cms (Reeder *pers. obs*.). In a UK study, floating mats of *Azolla filiculoides* were found to have a negative impact on the aquatic ecosystem, reducing the amount of light entering the water and reducing the growth of submerged macrophytes (Janes *et al*., 1996). Changes in the physiochemistry of the water beneath mats, in particular a reduction in dissolved oxygen, were also reported and have been linked with UK fish kills (Janes, 1998a).
2.13	How important is social and other harm caused by the organism within its existing geographic range?	major - 3	MEDIUM -1	In South Africa, thick mats of *A. filiculoides* are reported to have an negative impact on the quality of drinking water, such as bad odour, colour and turbidity. *Azolla* mats have also been associated with an increase in water borne, water-based and water-related diseases, increased siltation of rivers and dams, reduced water surface for recreation (fishing, swimming and water-skiing) and water transport, clogging of irrigation pumps, drowning of livestock and reduced water flow in irrigation canals (Hill and Cillers, 1999).
2.14	How important is the social harm likely to be in the Risk Assessment area?	moderate - 2	MEDIUM -1	Many of the problems reported above (see comments row 77, question 2.13) are the same. In the UK the effects on the quality of drinking water are probably negligible, as are possible effects on water borne diseases. Dense infestations, are a danger to livestock, children and pets who may attempt to walk onto surface without appreciating that there is deep water underneath.
2.15	How likely is it that genetic traits can be carried to native species, modifying their genetic nature and making their economic, environmental or social effects more serious?	very unlikely - 0	LOW - 0	*Azolla filiculoides* is known to hybridize with other *Azolla* spp. Van Cat *et. al*. (1989). *A. filiculoides* is probably the only species of *Azolla* present in the UK, therefore hybridization is extremely unlikely. Janes (1998b) reports, there is some evidence that *A. filiculoides* might have adapted to the British climate since its introduction.
2.16	How probable is it that natural enemies, already present in the Risk Assessment area, will have no affect on populations of the organism if introduced?	unlikely - 1	LOW - 0	The introduced weevil *Stenopelmus rufinasus* can be extremely damaging to *Azolla* populations in the UK (Reeder, unpublished). Other natural enemies include the waterlily aphid *Rhopalosiphum nymphaeae* and the snail *Chorebus gracilipes*. However, none of these herbivores have been recorded causing significant damage (Rostron, 1983).

2.17	How easily can the organism be controlled?	with some difficulty - 2	MEDIUM -1	Chemical control options for *A. filiculoides* are limited due to the small number of herbicides permitted for use in water. Floating mats can be sprayed with aquatic formulations of glyphosate that will kill all emergent and floating weeds onto which the spray is directed. Repeat applications are usually necessary, especially if the mat is thick. Due to a surface-area doubling time of 7-10 days, mechanical control is impractical on all but very small infestations. Successful control of *Azolla* using the frond-feeding weevil *Stenopelmus rufinasus* occurred in South Africa (Hill and Cilliers, 1999, McConnachie *et al* ., 2003, 2004). The weevil is also effective in the UK (Reeder, unpublished data).
2.18	How likely are control measures to disrupt existing biological or integrated systems for control of other organisms?	unlikely - 1	MEDIUM -1	The use of the broad spectrum herbicide glyphosate could potentially interfere with other biological systems if potential food plants were killed by the chemical.
2.19	How likely is the organism to act as food, a host, a symbiont or a vector for other damaging organisms?	moderately likely - 2	MEDIUM -1	*Azolla filiculoides* can act as a host for the waterlily aphid *Rhopalosiphum nymphaeae* . This aphid is extremely destructive in aquatic gardens and nurseries and is known to transmit at least five plant viruses including abaca mosaic, cabbage black ringspot, cauliflower mosaic, cucumber mosaic and onion yellow dwarf viruses. The aphid does have a relatively broad host range and does not rely on *Azolla* as a host.
2.20	Highlight those parts of the endangered area where economic, environmental and social impacts are most likely to occur	Still waters and lower (i.e. lentic) sections of water courses	LOW - 0	Virtually all low lying areas of the southern half of the Great Britain where static or slow moving water is found are at risk from infestation by this weed (see row 67 question 2.4). Economic losses are difficult to estimate in the UK, but *A. filiculoides* can impact significantly on fisheries, in terms of reduced surface area for fishing, control costs and loses due to fish kills. Economic costs of control will also be incurred wherever the weed is considered to be causing a nuisance. The environmental impacts of *Azolla* infestation (see comments row 78, question 2.14) are likely to be similar, wherever *Azolla* occurs, because of its tendency to form dense floating mats of vegetation. However, these impacts might be expected to be felt most acutely in areas with unique or diverse communities, such as Sites of Special Scientific Interest (SSSI) and conservation areas. The social impacts are felt in both urban and rural environments. In urban situations dense infestations are not only aesthetically unpleasing, but pose a danger to children and pets who may mistake the surface for land. In rural environments problems arise due to drowning of livestock, siltation of rivers, replacing of water pumps and the loss of water-based recreational activities. The geographic coverage of the weed could potentially expand if climate change were to influence the UK temperatures (see row 67, question 2.4) potentially making more sites in the northern halve of the UK suitable for colonisation.
	Summarise Entry	very likely - 4	LOW - 0	The species is already well established in the UK. There are five pathways of possible introduction, listed below in order of importance. 1) Intentional transfer and introduction by humans (e.g. plants for sale e.g. at garden centres and internet); 2) Unintentional transfer and introduction by humans (e.g. angling gear, discharge by aquarium keepers, contaminant of plant sales); 3) Natural dissemination along rivers and through movement of soil and water. Also spread on feet and feathers of birds; 4) Vegetative fragments on hulls of boats; 5) Ballast water (fresh water only).
	Summarise Establishment	very likely - 4	LOW - 0	The species is well adapted to slow and static water bodies in the UK, but does not tolerate turbulence or fast flowing water. *Azolla* can tolerate a broad range of environmental conditions; including extremes of pH, temperature, heavy metal and salt pollution and areas with low available nitrogen.
	Summarise Spread	rapid - 3	LOW - 0	The plant is spread in flood waters and by the movement of birds animals and man. *Azolla filiculoides* has been found in 669 (23%) of the 2823 10x10 km grid squares that make up Great Britain and 10 (0.7%) of the 1380 10x10 km grid squares that make up Northern Ireland. The 'New Atlas of the British and Irish Flora', published in 2002, includes an updated list of invasive aquatic weeds in which *A. filiculoides* is ranked number 25 with a rate of change of +2.76.
	Summarise Impacts	major - 3	MEDIUM -1	The plant has a high impact on biodiversity reducing populations of submerged macrophytes and invertebrates beneath the mats. Mats also reduce the amount of dissolved oxygen and can lead to fish kills under favourable conditions. Dense infestations, which completely cover the water surface, are a danger to children, pets and livestock who may mistake water for land. The dense cover of floating weeds also reduces the light level beneath the surface so that submerged weeds and algae die off causing serious deoxygenation problems. Free-floating weeds can be drawn into water intakes, blocking pumps and filters, and can mat together forming floating rafts, which cause flow problems and obstructions to weirs, locks and other structures.
	Conclusion of the risk assessment	HIGH -2		The species presents high risk in the southern half of England, and to static and slow moving water bodies in low lying areas of Northern Ireland. If the climate of the UK were to warm then perhaps the vulnerable area may extend some way further north and extend into higher altitude areas.
	Conclusions on Uncertainty		MEDIUM -1	

References

Ashton, P. J., Walmsley, R. D. (1976). The aquatic fern Azolla and its Anabaena symbiont. *Endeavour* **35:** 39-43.

Azolla control. (online) http://194.203.77.76/AzollaControl/default.htm. Accessed (5/1/09)

Baars, J-R. (2008). Invasive Species Ireland, Case Study 4, Water fern, *Azolla filiculoides* – Under biological control in Ireland {0nline} http://www.invasivespeciesireland.com/files/public/Case%20Studies/Case%20Study%204%20-%20Biological%20control.pdf. Accessed (5/1/09)

Centre for Ecology and Hydrology Information sheet 22 *Azolla filiculoides* Water fern (online) Available http://www.nerc-wallingford.ac.uk/research/capm/pdf%20files/22%20Azolla%20filiculoides.pdf. Accessed (4/1/2009)

Clapham, A. R., Tutin, T. G. and Warburg, E. F. (1962). *Flora of the British Isles* , 2nd ed. Cambridge. 1269p.

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

Forni, C., Tel-Or, E. ,Bar, E. Grilli-Caiola. M. (1991). Effects of antibiotic treatments on *Azolla-Anabaena* and *Arthrobacter*. *Plant Soil* , **137**:151-155.

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.

Hill, M. P. (1998). Life history and laboratory host range of *Stenopelmus rufinasus* , a natural enemy for *Azolla filiculoides* in South-Africa. BioControl **43** (2): 215-224.

Hill, M. P., Cilliers, C. J. (1999). *Azolla filiculoides* Lamarck (Pteridophyta: *Azollaceae),* its status in South Africa and control. *Hydrobiologia* **415**: 203-206.

Janes, R. (1998a). Growth and survival of *Azolla filiculoides* in Britain. 1. Vegetative reproduction. *New Phytologist* **138**: 367-376.

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

Janes, R., Eaton, J. W., Hardwick, K. (1996). The effects of floating mats of *Azolla filiculoides* Lam. and *Lemna minuta* Kunth on the growth of submerged macrophytes. *Hydrobiologia* **340**: 23-26.

Jansen, O. E. (1921). *Entomologists' Monthly Magazine* **57**: 225-6.

Kitoh, S., Shiomi, N., Uheda, E. (1993). The growth and nitrogen fixation of *Azolla filiculoides* Lam. in polluted water. *Aquatic botany* **46**: 129-139.

Lejeune, A, Cagauan, A, Van Hove, C. (1999). Azolla research and development : Recent trends and priorities. Symbiosis **2**: 333-351

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

McConnachie, A. J., Hill, M. P., Byrne, M. J. (2004). Field assessment of a frond-feeding weevil, a successful biological control agent of red waterfern, *Azolla filiculoides* , in southern Africa. *Biological control* **29**: 326-331.

McConnachie, A. J., Wit, M. P. de, Hill, M. P., Byrne, M. J. (2003). Economic evaluation of the successful biological control of *Azolla filiculoides* in South Africa. *Biological Control* **28**: 25-32.

Moon, H. P. (1974). *Azolla filiculoides* . *Leicestershire. Newsletter. of the Natural History Section of the Leicester Literary and Philosophical Society* **18**: 5-9.

Moore, A.W. (1969). *Azolla:* biology and agronomic significance. *Botanical Review* **35**: 17-35.

Peters, G. A. (1976). *Studies on the Azolla-Anabaena azollae symbiosis* . In W. E. Newton and C. J. Nylan, eds. Proceedings of the First International Symposium on Nitrogen Fixation. Vol. 2: 592-610. Washington Sate Univ. Press, Pullman

Preston, C. D., Croft, S M. (1997). *Aquatic Plants in Britain and Ireland.* Colchester: Harley Brooks: 365p.

Preston, C. D., Pearman, D. A. and Dines, T. D. (2002). *New atlas of the British and Irish flora* . Oxford University Press, Oxford: 910p.

Stace, C. A. (1997). *New flora of the British Isles* . 2nd ed. Cambridge University Press. Cambridge: 1130p.

Rostron, J. C. (1983). The distribution of *A. filiculoides* in Britain. Department of Human Sciences, Loughborough University.

Tung, H. F., Watanabe, I. (1983). Differential response of *Azolla-Anabaena* associations to high temperatures and minus phosphorus treatments. *New Phytologist* **93**: 423-431.

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.

Zheng, W. Bergman, B. Chen, B. Zheng, S. Xiang, G. Rasmussen, U. (2008).Cellular responses in the cyanobacterial symbiont during its vertical transfer between plant generations in the Azolla microphylla. *New Phytologist* **181**(1):53-61.