# RISK ASSESSMENT SUMMARY SHEET

Updated: September 2015

## Quagga mussel (*Dreissena rostriformis bugensis*)


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- Freshwater mussel from the Ponto-Caspian region.
- Similar in size to the non-native zebra mussel (which it can out-compete ).
- Recorded in west London, previously on top of the horizon scanning list. Risk assessment was completed before this invasion was discovered.
- Prefers slow flowing waters such as reservoirs, canals and lakes.
- Highly invasive with potentially huge impacts on fresh waters across GB. Has already invaded Western Europe and North America.

### History in GB

One population in GB (near Egham, Surrey). Nearest European population is in the Netherlands (where it was first recorded in 2006). Has yet to be recorded in Rotterdam – which is mainly freshwater and has extensive trade with the UK.

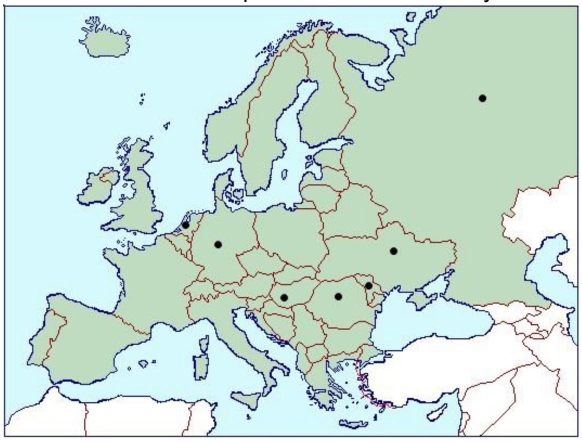
### Native distribution

Ponto-Caspian region of SE Europe – mainly lower reaches of rivers in Ukraine.


Source: NNSIP

### Distribution in EU

Black circles indicate presence within country



Source: Cabi 2013

### Impacts

Environmental (massive)

- Driver of massive ecosystem change in lentic systems.
- It has a huge impact on water clarity due to its massive filtration capacity.
- Changes nutrient availability, alters abundance of many taxa including macrophytes, amphipods and zooplankton.
- Likely to cause declines in some threatened bivalves and gastropods.

Economic (major)

- Potentially large negative impact on water industry due to blockage of pipes, filters, turbines etc.

Social (minor)

- Blue-green algal blooms may pose risk to humans and livestock.

**Introduction pathways**

Recreational boating (likely)
Ballast water (moderately likely) – risk will increase if Rotterdam becomes infested
Angling (moderately likely) – larvae in bait buckets or fish wells on boats from near continent
Contamination (moderately likely) – as contaminants on plants for landscaping

**Spread pathways**

Natural (rapid) – rapid dispersal (10's of km PA) within a catchment. Rapid spread between catchments via canals
Human (rapid) - fouling of vessel and contamination of angling gear likely to be the main vectors

### Summary

| | Risk | Confidence |
|---|---|---|
| Entry | **VERY LIKELY** | **VERY HIGH** |
| Establishment | **VERY LIKELY** | **VERY HIGH** |
| Spread | **RAPID** | **HIGH** |
| Impacts | **MAJOR** | **VERY HIGH** |
| Conclusion | **HIGH** | **VERY HIGH** |

# RISK ASSESSMENT COVERING PAGE - ABOUT THE PROCESS

**It is important that policy decisions and action within Great Britain are underpinned by evidence. At the same time it is not always possible to have complete scientific certainty before taking action. To determine the evidence base and manage uncertainty a process of risk analysis is used.**

Risk analysis comprises three component parts: risk assessment (determining the severity and likelihood of a hazard occurring); risk management (the practicalities of reducing the risk); and risk communication (interpreting the results of the analysis and explaining them clearly). This tool relates to risk assessment only. The Non-native Species Secretariat manages the risk analysis process on behalf of the GB Programme Board for Non-native Species. During this process risk assessments are:

- Commissioned using a consistent template to ensure the full range of issues is addressed and to maintain a comparable quality of risk and confidence scoring supported by appropriate evidence.
- Drafted by an independent expert in the species and peer reviewed by a different expert.
- Approved by the NNRAP (an independent risk analysis panel) only when they are satisfied the assessment is fit-for-purpose.
- Approved 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.

**Common misconceptions about risk assessments**

The risk assessments:

- consider only the risks (i.e. the chance and severity of a hazard occurring) 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.
- 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-based decision on appropriate management.
- are advisory and therefore are part of the suite of information on which policy decisions are based.
- are not final and absolute. They are an assessment based on the evidence available at that time. Substantive new scientific evidence may prompt a re-evaluation of the risks and/or a change of policy.

**Period for comment**

Once drafted and approved by the NNRAP and GB Programme Board, risk assessments are open for stakeholders to provide comment on the scientific evidence which underpins them for three months from the date of posting on the NNSS website. Relevant comments are collated by the NNSS and sent to the risk assessor for them to consider and, if necessary, amend the risk assessment. Where significant comments are received the NNRAP will determine whether the final risk assessment suitably takes into account the comments provided.

**To find out more:** published risk assessments and more information can be found at https://secure.fera.defra.gov.uk/nonnativespecies/index.cfm?sectionid=22

# GB NON-NATIVE ORGANISM RISK ASSESSMENT SCHEME

**Name of organism:** Quagga mussel (*Dreissena rostriformis bugensis*)
**Author:** David Aldridge
**Version:** Final (April 2016) – Original draft August 2011; signed off by NNRAP February 2013; approved by GB Programme Board December 2014; published on NNSS website September 2015.
**Risk Assessment Area:** Great Britain (England, Scotland, Wales and their islands)

Note: this risk assessment was completed before quagga mussel was detected in GB waters.

## SECTION A – Organism Information and Screening

| **Stage 1. Organism Information** | **RESPONSE** | **COMMENT** |
|---|---|---|
| 1. Identify the organism. Is it clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank? | Yes, this is a 'good' species with clear external diagnostic features. | Genetic analyses by Therriault et al. (2004) showed that *Dreissena bugensis* (Andrusov) and *Dreissena rostriformis* (Deshayes) were the same species. The species is now accepted as *Dreissena rostriformis bugensis*. |
| 2. 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 | |
| 3. Does a relevant earlier risk assessment exist? (give details of any previous risk assessment) | No | |
| 4. If there is an earlier risk assessment is it still entirely valid, or only partly valid? | N/A | |
| 5. Where is the organism native? | Ponto Caspian region | The mouths of the Southern Bug, Dneiper, and lower Inguletz Rivers, Ukraine. |
| 6. What is the global distribution of the organism (excluding Great Britain)? | The species has spread into Eastern and Western Europe and North America. | In the last few decades the species has extended its range on Russia, now occupying the Volga River, Don River and Volga-Don canal (Son, 2007). The species was reported in the Danube, Romania, in 2004 (Popa & Popa, 2006). In April 2006 it was discovered in Western Europe, near Willemstad, The Netherlands (Molloy et al., 2007), and a year later in the Main River, Germany (Van der Velde & Platvoet, 2007). The species probably invaded the North American Great Lakes |

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| | | simultaneously with the zebra mussel, Dreissena polymorpha, in the mid 1980s. It was recognised for the first time in 1991 (Spidle et al. 1994) and has since spread broadly across the eastern and western United States, as far south as the border with Mexico. |
| 7. What is the distribution of the organism in Great Britain? | It has not yet been recorded in GB | |
| 8. Is the organism known to be invasive (i.e. to threaten organisms, habitats or ecosystems) anywhere in the world? | Yes. | The species is known to be invasive throughout its non-native range (e.g. Cuhel & Aguilar, 2013). In parts of North America and Europe the quagga mussel has been seen to replace zebra mussels. |
| **Stage 2. Screening Questions** | | |
| 9. Has this risk assessment been requested by the **GB** Programme Board? | Yes<br><br>If yes, go to section B (detailed assessment)<br>If no, got to 10 | |

## SECTION B – Detailed assessment

# PROBABILITY OF ENTRY

Important instructions:

- For organisms which are already present in GB, only complete the entry section for current active pathways of entry or if relevant potential future pathways. The entry section need not be completed for organisms which have entered in the past and have no current pathways of entry.

Notes:

- Entry is defined as the movement of an organism from outside of GB into GB either into the wild or into containment. Examples of entry include ...
- A pathway is defined as any means that allows the entry or spread of a pest
- Examples of pathways include shipping, escape from wildlife collections, horticulture trade, pet trade, etc.

| QUESTION | RESPONSE | CONFIDENCE | COMMENT |
|---|---|---|---|
| 1.1. How many active pathways are relevant to the potential entry of this organism?<br><br>(If there are no active pathways or potential future pathways respond N/A and move to the Establishment section) | **many** | **very high** | The ‘track record’ of the Zebra mussel is a useful guide for predicting likely vectors and pathways of the Quagga mussel. |
| 1.2. List relevant pathways through which the organism could enter. Where possible give detail about the specific origins and end points of the pathways.<br><br>For each pathway answer questions 1.3 to 1.10 (copy and paste additional rows at the end of this section as necessary). | 1. Ballast water discharge<br>2. Movement of recreational craft<br>3. Angling<br>4. Contaminant<br>5. Stocking | | |

| Pathway name: | **1. Ballast Water Discharge** | | |
| --- | --- | --- | --- |
| 1.3. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)?<br><br>(If intentional, only answer questions 4, 9, 10, 11) | **Accidental** | **high** | |
| 1.4. 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?<br><br>Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place. | **unlikely** | **high** | Quagga mussels are likely to have been introduced to North America in ballast water of transoceanic ships. The Netherlands is currently the EU country that exchanges the greatest volume of trade with the UK, with the largely freshwater port of Rotterdam accounting for 7.6% of total tonnage loaded and unloaded at UK ports in 2008 (Talbot et al., 2008). However, at present, the species is not known from Rotterdam so this pathway will become more important in future years as the Quagga mussel continues to spread through The Netherlands.<br><br>Unlike many countries, GB has relatively few freshwater ports, and so ballast water discharge may not be an especially important pathway. The tolerance of Quagga mussels to brackish water conditions (<5ppt; Spidle, 1994) increases the risk. |
| 1.5. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)?<br><br>Subnote: In your comment consider whether the organism could multiply along the pathway. | **very likely** | **very high** | Dreissenid veliger larvae can survive in ballast tanks for up to three weeks before settling. This would enable transport from both the native and invaded ranges. Transport into N. America is believed to have been through ballast water discharge into the Great Lakes. |

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| 1.6. How likely is the organism to survive existing management practices during passage along the pathway? | **Unlikely if ballast water exchange is undertaken.** | **high** | Shipping has been an important vector for species establishment (Lodge et al. 2006) and will likely increase in strength as shipping traffic grows. In response, the International Maritime Organization adopted the International Convention for the Control and Management of Ships Ballast Water and Sediments in 2004 (http://globallast.imo.org). The convention is not yet in force because many nations, including the United Kingdom, have not ratified it (Keller et al., 2009). The global nature of the shipping industry means that ratifying this convention to hasten its enforcement may be the best approach for reducing future introductions through ballast water. |
| 1.7. How likely is the organism to enter GB undetected? | **likely** | **very high** | There are no routine screening processes to detect dreissenid veliger larvae in ballast water. |
| 1.8. How likely is the organism to arrive during the months of the year most appropriate for establishment? | **likely** | **high** | Quagga mussels reproduce when water temperatures reach 10˚C, meaning that veligers may be present in water from spring to autumn. |
| 1.9. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host? | **moderately likely** | **high** | The tolerance of Quagga mussels to brackish water conditions (<5ppt) increases the risk of transport via this pathway. |
| 1.10. Estimate the overall likelihood of entry into GB based on this pathway? | **moderately likely** | **high** | Moderately likely at present, but the likelihood will increase as the species spreads through The Netherlands. This risk will be somewhat reduced if ballast water exchanges are conducted at sea. |

| Pathway name: | **2. Movements of recreational craft** | | |
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| 1.3. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)?<br><br>(If intentional, only answer questions 4, 9, 10, 11) | **Accidental** | **very high** | |
| 1.4. 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?<br><br>Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place. | **moderately likely** | **very high** | Veliger larvae may be transported in bilge waters or damp regions of boats being transported from mainland Europe. There is considerable movement of pleasure craft from the Rhine to GB.<br>Adult mussels may be transported on the hulls of boat traffic moving from The Netherlands to GB (Sylvester & MacIsaac, 2010).<br><br>Perhaps one of the greatest risks comes from international watersports events hosted in GB e.g. canoeing, jet skiing, power boating, sailing. Often such craft are moved overland to GB within relatively short timeframes, and may therefore carry viable veligers or live adults attached to the craft themselves, or attached weed, or the trailers used to transport them. Recreational boats and trailers are a major pathway for the spread of dreissenids in North America. |
| 1.5. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)?<br><br>Subnote: In your comment consider whether the organism could multiply along the pathway. | **very likely** | **very high** | Veliger larvae can remain in the water column for three to four weeks, and so can withstand considerable journeys (Claudi & Mackie, 1993). Adult quagga mussels can tolerate overland dispersal of three to five days transport from infested water bodies (Ricciardi et al, 1995). Quagga mussels cannot tolerate salinities >5 ppt, |

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| | | | so would not survive a journey attached to the hull of a boat that passed through an ocean (Spidle et al., 1995).<br><br>None of these pathways would permit the organisms to multiply. |
| 1.6. How likely is the organism to survive existing management practices during passage along the pathway? | **very likely** | **very high** | There are no routine management practices to control for these pathways. However, the emerging Check, Clean, Dry initiative may help to reduce risk at international watersports events if incoming vessels are processed suitably before entering the water. |
| 1.7. How likely is the organism to enter GB undetected? | **very likely** | **very high** | Dreissenid veligers are 40 µm (Claudi & Mackie, 1993) and so would not be detected during any visual inspections. Juvenile mussels of 1mm can be attached to weeds and other surfaces, and are unlikely to be seen by eye. |
| 1.8. How likely is the organism to arrive during the months of the year most appropriate for establishment? | **very likely** | **high** | Juvenile and adult mussels may pass into GB in a viable form at any time of the year. However, dreissenid veliger larvae in Europe will typically be present in water temperatures ≥12°C (Bacchetta et al, 2010) which typically would encompass March to November in GB. This would coincide with most recreational and sporting activities in GB lakes and rivers, which take place during the summer time. |
| 1.9. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host? | **very likely** | **very high** | Adult Quagga mussels can become relatively easily dislodged, while fouled weeds would readily fall into a new reservoir. Veligers could enter the water column on wet equipment, including wetsuits and from the vessels themselves. |

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| 1.10. Estimate the overall likelihood of entry into GB based on this pathway? | **very likely** | **very high** | This is the most likely pathway of introduction. Boating events, in particular, are likely to involve movement of craft from highly suitable sites in the European mainland and into equally suitable sites in GB. Further, the transport time for these craft and associated equipment is likely to enable survival along this pathway. |

| Pathway name: | **3. Angling** | | |
|---|---|---|---|
| 1.3. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)?<br><br>(If intentional, only answer questions 4, 9, 10, 11) | **Accidental and intentional** | **high** | |
| 1.4. 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?<br><br>Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place. | **unlikely** | **medium** | Adult mussels are favoured bait for some anglers and so may be transported from mainland Europe to GB. Veliger larvae may travel accidentally within bait buckets and live fish holding wells in boat craft.<br><br>Angling is one of the most popular hobbies in GB, although it is unlikely that many anglers will specifically select sites in Europe to fish where Quagga mussels are also currently known. |
| 1.5. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)?<br><br>Subnote: In your comment consider whether the organism could multiply along the pathway. | **very likely** | **very high** | As for (2) movement of recreational craft |
| 1.6. How likely is the organism to survive existing management practices during passage along the pathway? | **very likely** | **very high** | As for (2) movement of recreational craft |
| 1.7. How likely is the organism to enter GB undetected? | **very likely** | **very high** | As for (2) movement of recreational craft. Adult mussels transported for bait are unlikely to be questioned at border controls. |

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| 1.8. How likely is the organism to arrive during the months of the year most appropriate for establishment? | **very likely** | **very high** | As for (2) movement of recreational craft. Angling trips are most likely to take place during the summer. |
| 1.9. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host? | **very likely** | **very high** | Most GB angling sites (lakes, rivers) are likely to provide suitable habitat for Quagga mussels. |
| 1.10. Estimate the overall likelihood of entry into GB based on this pathway? | **Moderately unlikely** | **high** | |

| Pathway name: | **4. Contaminant** | | |
|---|---|---|---|
| 1.3. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)?<br><br>(If intentional, only answer questions 4, 9, 10, 11) | **Accidental** | **high** | |
| 1.4. 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?<br><br>Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place. | **very unlikely** | **high** | There is growing anecdotal evidence that a number of introductions of the zebra mussel into GB reservoirs has been through the contamination of plants introduced for landscaping or habitat restoration programmes.<br><br>At present, this pathway is unlikely to be important but the risk will increase as Quagga mussels continue to spread across mainland Europe. |
| 1.5. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)?<br><br>Subnote: In your comment consider whether the organism could multiply along the pathway. | **very likely** | **very high** | Adult mussels can attach to the stems of water plants and survive overland transport in wet and muddy conditions for over one week (D. Aldridge, personal observations). |
| 1.6. How likely is the organism to survive existing management practices during passage along the pathway? | **very likely** | **high** | There is no routine screening of reeds that are introduced into lakes and reservoirs for habitat restoration. Nor is there a clear approach for the screening of European water plants which may be imported from open environment propagation sites in mainland Europe. Screening is critical for prevention. |
| 1.7. How likely is the organism to enter GB | **very likely** | **very high** | Rhizomes and stem surfaces are unlikely to be |

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| undetected? | | | inspected. |
| 1.8. How likely is the organism to arrive during the months of the year most appropriate for establishment? | **very likely** | **very high** | Any time of year would be suitable for adult mussels to be transported in a viable state. |
| 1.9. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host? | **very likely** | **very high** | The location of planting is likely to be similar to the source location. |
| 1.10. Estimate the overall likelihood of entry into GB based on this pathway? | **moderately likely** | **high** | There is little information on the frequency with which such introductions take place. The reported introductions of Zebra mussels into GB reservoirs have been GB to GB transfers. |

| Pathway name: | **5. Stocking** | | |
|---|---|---|---|
| 1.3. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)?<br><br>(If intentional, only answer questions 4, 9, 10, 11) | **Intentional** | **very high** | |
| 1.4. 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?<br><br>Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place. | **unlikely** | **high** | Zebra mussels have been introduced purposefully into GB locations to serve as water clarifiers (e.g. Salford Quays). They have also been introduced into diving lakes to provide clearer water and as items of biological curiosity. There is a low chance that purposeful introductions in the future may result from collection of mussels from mainland Europe. |
| 1.9. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host? | **very likely** | **very high** | GB is climatically matched to some of the mainland Europe sites for this species (e.g. the lower Rhine). Introduction is likely to be undertaken based on an assumption of habitat suitability. |
| 1.10. Estimate the overall likelihood of entry into GB based on this pathway? | **very unlikely** | **high** | Zebra mussels from GB are likely to offer an easier option for those wishing to introduce biological water clarifiers. Most reputable consultancy companies would recognise the dangers of introducing a non-native organism in GB waters. Section 14 of the Wildlife and Countryside Act, 1981, makes it an offence to release non-native species into GB freshwaters, thus making commercial stocking an unlikely route of introduction. |

# PROBABILITY OF ESTABLISHMENT

Important instructions:

- For organisms which are already well established in GB, only complete questions 1.15 and 1.21 then move onto the spread section.

Notes:

- Establishment is defined as the perpetuation, for the foreseeable future, of a pest within an area after entry.

| QUESTION | RESPONSE | CONFIDENCE | COMMENT |
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| 1.12. How likely is it that the organism will be able to establish in GB based on the similarity between climatic conditions in GB and the organism's current distribution? | **very likely** | **very high** | Quagga mussels are replacing Zebra mussels in the lower Rhine (van der Velde et al, 2010); a region with a similar climate to GB. Preliminary bioclimatic models (Gallardo & Aldridge, in review) show a strong suitability across much of England. |
| 1.13. How likely is it that the organism will be able to establish in GB based on the similarity between other abiotic conditions in GB and the organism's current distribution? | **very likely** | **very high** | Quagga mussels favour lentic systems, such as reservoirs and lakes. They are not found in fast flowing rivers, but canals provide ideal habitats. British freshwaters provide a wealth of suitable hard substrates which has already been seen to support the widespread establishment of Zebra mussels. As populations establish, shell material enables expansion into muddy substrates (Bially & MacIsaac, 2000).<br><br>Quagga mussels require ≥12 mg/l calcium in the water compared with ≥ 8 mg/l for Zebra mussels (Jones & Ricciardi, 2005). Whittier et al (2008) suggested that risk was very high for sites with ≥ 28 mg/l calcium. General studies in North America suggest that the most favourable conditions for Quagga mussels are an alkalinity of >90 mg CaCO3/l, pH 8.0-8.6, dissolved oxygen > 8mg/l, conductivity > 85 µS/cm, total phosphorus 10-15 µg/l (Renata Claudi, personal |

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| | | | communications). The species cannot survive in salinities > 5ppt (Spidle, 1994). In North America, Quagga mussels have been found at depth of 130m, but in Russia the maximum reported depth is 28m (Mills et al., 1996). |
| 1.14. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, terraria, zoological gardens) in GB?<br><br>Subnote: gardens are not considered protected conditions | **unlikely** | **very high** | Most protected conditions are unlikely to provide suitable habitat due to the shallow nature of the water. Ultraviolet light prevents settlement of dreissenid veligers in shallow water (Claudi & Mackie, 1993). |
| 1.15. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in GB? | **widespread** | **very high** | Bioclimatic models (see 1.12) suggest there is wide suitability within GB. As a rule of thumb, it can be assumed that the widespread distribution of Zebra mussels in GB will be similarly matched by Quagga mussels, which will replace the Zebra mussels in many sites. Distribution is likely to include much of England, western and southern Wales and central Scotland. |
| 1.16. 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 GB? | **N/A** | **N/A** | No other species are required. |
| 1.17. How likely is it that establishment will occur despite competition from existing species in GB? | **very likely** | **very high** | The only species with which Quagga mussels will directly compete in GB is the invasive Zebra mussel (*Dreissena polymorpha*). Throughout its invaded range, Quagga mussels have been seen to replace Zebra mussels in most habitats (Wilson et al., 2006; van der Velde et al, 2010). This has been attributed to the lower respiration rates, greater shell growth, greater shell mass, faster filtration rates and greater assimilation efficiency (Diggins, 2001; Baldwin et al., 2002; |

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| | | | Stoeckmann, 2003). Zebra mussels appear to find refugia from Quagga mussels in certain habitats, including those with fast flow, and areas with macrophyte substrate onto which Zebra mussels preferentially attach (Diggins et al., 2004). |
| 1.18. How likely is it that establishment will occur despite predators, parasites or pathogens already present in GB? | **very likely** | **very high** | Declines in Quagga mussels in parts of Russia have been attributed to fish predation (Zhulicov et al., 2006). Quagga mussels produce fewer byssal threads than Zebra mussels (Peyer et al, 2009), so are more readily removed from hard surfaces than Zebra mussels. However, it is likely that natural predation is unlikely to regulate Quagga mussels, especially if they quickly establish large densities after which the intertwining of byssal threads can make removal by predators very unlikely. Certainly, no predators in The Netherlands have been found to regulate Quagga mussel populations, and we would expect similar biotic interactions in GB. |
| 1.19. How likely is the organism to establish despite existing management practices in GB? | **very likely** | **very high** | No GB management practices are likely to prevent establishment. |
| 1.20. How likely are management practices in GB to facilitate establishment? | **unlikely** | **high** | Existing GB management practices are unlikely to contribute to a faster or greater chance of establishment. Disturbance may partly facilitate establishment by creating empty niches, but Quagga mussels will typically exploit a niche not occupied by native biota, or will competitively exclude zebra mussels. |
| 1.21. How likely is it that biological properties of the organism would allow it to survive eradication campaigns in GB? | **likely** | **high** | No reported eradication attempts have been made for Quagga mussels. It is likely that at first discovery in GB, Quagga mussels will already have established a large population. An eradication attempt is therefore unlikely to kill every individual. This is exacerbated by |

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| | | | the fact that dreissenids can be protected from toxicants by closing their shell valves (Aldridge et al., 2006). A single adult mussel can produce 1 million veliger larvae (Claudi & Mackie, 1993), and so eradication attempts would also need to target veligers within the water column. |
| 1.22. How likely are the biological characteristics of the organism to facilitate its establishment? | **likely** | **high** | Quagga mussels can tolerate a wide range of habitat conditions, including lotic and lentic systems (see 1.13). External release of gametes increases the chance of two introduced adults achieving reproductive success. The fact that Quagga mussels attach to one another to form a 'druss' increases the chance that introduced adults would be within close proximity. |
| 1.23. How likely is the capacity to spread of the organism to facilitate its establishment? | **very likely** | **very high** | A single adult mussel can produce 1 million veliger larvae (Claudi & Mackie, 1993). Veligers can remain in the water column for three to four weeks. If Quagga mussels are introduced as veligers, there is a relatively high change of a number of these individuals to settle on a suitable substrate. |
| 1.24. How likely is the adaptability of the organism to facilitate its establishment? | **likely** | **high** | Quagga mussels are known to have a highly plastic morphology, which can enable phenotypes to develop which a well suited to different temperature regimes, water depth, food quantity and water motion (Peyer et al., 2010) |
| 1.25. How likely is it that the organism could establish despite low genetic diversity in the founder population? | **likely** | **high** | The plasticity of the Quagga mussel suggests that founder effects may be a relatively small barrier to establishment. Genetic studies of Quagga mussels in North America found high genetic diversity with no evidence for founder effects (Brown & Stepien, 2010). Imo et al. (2010) found no evidence for founder effects and minimal genetic differentiation in Quagga mussel |

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| | | | populations from Germany, North America and the southeast Danube. |
| 1.26. Based on the history of invasion by this organism elsewhere in the world, how likely is to establish in GB? (If possible, specify the instances in the comments box.) | **very likely** | **very high** | It seems only a matter of time before the species establishes in GB. The current rate of establishment in The Netherlands (van der Velde et al., 2010) coupled with the bioclimatic and biotic similarities between The Netherlands and many GB waterways indicates this species has a 'track record' which is likely to be replicated in GB. |
| 1.27. If the organism does not establish, then how likely is it that transient populations will continue to occur?<br><br>Subnote: Red-eared Terrapin, a species which cannot re-produce in GB but is established because of continual release, is an example of a transient species. | **N/A** | **N/A** | It is likely to establish. |
| 1.28. Estimate the overall likelihood of establishment (mention any key issues in the comment box). | **very likely** | **very high** | The highly successful establishment of Quagga mussels in Germany and The Netherlands suggest similar success in GB due to strong bioclimatic similarity. Establishment is likely due to close proximity to established populations which shortens transport times, the capacity of veligers and adults to survive overland dispersal, the frequency of suitable vectors (e.g. watercraft) to move between highly suitable locations, the absence of any effective management strategies, the likelihood of more than one founding individual to be introduced at one time (many veligers, or adults in a druss), the wide habitat tolerances and the highly plastic and adaptable nature of the species. |

# PROBABILITY OF SPREAD

Important notes:

- Spread is defined as the expansion of the geographical distribution of a pest within an area.

| QUESTION | RESPONSE | CONFIDENCE | COMMENT |
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| 2.1. How important is the expected spread of this organism in GB by natural means? (Please list and comment on the mechanisms for natural spread.) | **massive** | **very high** | A single adult can produce 1 million veligers in a season and veligers can pass through river systems for up to three or four weeks before settling. This has enabled dreissenid veligers to travel 300km in one season in the USA (Bially & MacIsaac, 2000). Tolerance of both lentic and slow-moving lotic systems suggest the mussel could quickly move from a lake or reservoir into recipient river systems. Veligers are vulnerable to UV radiation (Claudi & Mackie, 1993), so transport through shallow waters is less likely. |
| 2.2. How important is the expected spread of this organism in GB by human assistance? (Please list and comment on the mechanisms for human-assisted spread.) | **massive** | **very high** | The track record of Zebra mussels in GB shows that human-assisted spread is highly likely. Canals will provide ideal habitat and enable movement between different river systems. Fouling on commercial vessels and pleasure craft will speed up rates of spread, especially upstream. Most of the factors detailed in 1.2 will also facilitate spread in GB (Movement of recreational craft, angling, contaminants, stocking). |
| 2.3. Within GB, how difficult would it be to contain the organism? | **major** | **high** | When the mussel is first discovered, it is highly likely that it will have already reached a large population size. If the mussel is discovered first in a reservoir or isolated lake, then containment will be more feasible. Success in containing killer shrimps in GB reservoirs illustrates that containment may be possible in the short term. |

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| | | | However, it would be impossible to contain a riverine population due to the dispersal of veligers. |
| 2.4. Based on the answers to questions on the potential for establishment and spread in GB, define the area endangered by the organism. [text] | | **high** | Much of England, especially in areas with high alkalinity. Eastern and southern Wales, central Scotland. Standing, deep water bodies, such as lakes and reservoirs may be especially vulnerable, as will be canals. It is likely that the niches of Zebra Mussel and Quagga Mussel will differ to some extent, although there is no published evidence for this. |
| 2.5. What proportion (%) of the area/habitat suitable for establishment, if any, has already been colonised by the organism? | **0** | **very high** | This species in not present in GB to our knowledge. There is already a high awareness of this species and our own surveys take us across much of GB each year looking at Zebra mussels. |
| 2.6. What proportion of the area/habitat 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** | **medium** | There is a strong chance of establishment in GB over the coming years. Small founding population size and the effects of possible containment activities may help to reduce initial spread rates. |
| 2.7. What other timeframe would be appropriate to estimate any significant further spread of the organism in Great Britain? (Please comment on why this timeframe is chosen.) | **10, 20, 40** | **medium** | The Zebra mussel had broadly reached its current British geographical distribution in the 40 years following first discovery in 1824 (Aldridge, 2010). Once populations have established in a major GB river, the interconnectivity of our waterways will facilitate rapid spread and increase the potential for salutatory spread by humans. |
| 2.8. In this timeframe what proportion of the endangered area/habitat (including any currently occupied areas/habitats) is likely to have been invaded by this organism? | **67-90** | **medium** | Value given for 40 years. Based on experiences of Zebra mussels in GB (Aldridge, 2010) and Quagga mussels in Germany, Russia and The Netherlands (Orlova et al., 2004; Imo et al., 2010; van der Velde et al., 2010). |
| 2.9. Estimate the overall potential for future spread for this organism in Great Britain (using the comment box to | **rapid** | **medium** | The wide habitat range of the species, coupled with the considerable interconnectivity of GB waterways |

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| indicate any key issues). | | | suggests rapid spread. It is likely that there will be an initial lab in spread following first discovery, because funding populations may still be small and isolated, and containment strategies may be effective. |

# PROBABILITY OF IMPACT

Important instructions:

- When assessing potential future impacts, climate change should not be taken into account. This is done in later questions at the end of the assessment.

Notes:

- Where one type of impact may affect another (e.g. disease may also cause economic impact) the assessor should try to separate the effects (e.g. in this case note the economic impact of disease in the response and comments of the disease question, but do not include them in the economic section).

| **QUESTION** | **RESPONSE** | **CONFIDENCE** | **COMMENTS** |
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| 2.10. How great is the economic loss caused by the organism within its existing geographic range (excluding GB), including the cost of any current management? | **massive** | **very high** | Estimates in the US do not separate the economic effects of Zebra and Quagga mussels. Estimates range have been given as high as $US1-5 bn per year (Pimental, 2001). The annual economic cost to water pipes, turbines and filters is placed at $US 167-467 (Connelly et al., 2007). |
| 2.11. How great is the economic cost of the organism currently in GB excluding management costs (include any past costs in your response)? | **minimal** | **very high** | It has not yet been found in GB. |
| 2.12. How great is the economic cost of the organism likely to be in the future in GB excluding management costs? | **major** | **very high** | Quagga mussels may affect many ecosystem services. Recreational revenue may be lost from angling lakes, sporting activities may be lost if Quagga mussels encourage the development of toxic cyanobacetria within lakes and reservoirs. Fouling of boat hulls creates drag and can reduce fuel efficiencies by 30% (Oreska & Aldridge, 2010). Blockage of water transfer pipes increases fuel spend from increased pumping costs and may cost the GB water industry >£1m per year (Anglian Water, personal communication). |

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| 2.13. How great are the economic costs associated with managing this organism currently in GB (include any past costs in your response)? | **minimal** | **very high** | It has not yet been found in GB. |
| 2.14. How great are the economic costs associated with managing this organism likely to be in the future in GB? | **massive** | **high** | Oreska & Aldridge (2010) estimated the annual direct cost attributable the management of Zebra mussels in GB to approximate £4.5m. Quagga mussels may replace much of this problem, so it may be viewed that one economic cost is simply being replaced by another. However, the difference in habitat requirements will mean that Quagga mussels will invade new localities and may reach different population densities. The tendency for Quagga mussels to be sloughed from pipelines that experience sudden increases in flow (Peyer et al., 2009) could present a new risk to waterworks and power plants. If there is a greater perceived risk to a works being taken out of action, management costs will probably be greater. |
| 2.15. How important is environmental harm caused by the organism within its existing geographic range? | **massive** | **very high** | Dreissenid mussels are keystone taxa and ecosystem engineers (Sousa et al., 2010). They drive dramatic changes in biodiversity and ecosystem function through direct and indirect effects (MacIsaac, 1996; Sousa et al., 2010). Quagga mussels are listed as one of the globally most harmful invaders.<br><br>Cuhel & Aguilar (2013) identify three crucial traits which might explain how quagga mussels rapidly replaced zebra mussels in the Great Lakes of North America: (*a*) active feeding at winter and deepwater temperatures (0.5◦C –5◦C)); (*b*) a lower metabolic rate, leading to higher assimilation efficiency (ability to survive or even grow on less food than zebra mussels; and (*c*) the ability to colonize a wider range of substrate types, including clay, sand and consolidated sediment. |

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| | | | Quagga mussels have populated clay and sand surfaces surrounding zebra mussel-encrusted rocky substrates, and during the winter they cleared the water of plankton while zebra mussels were dormant. When the zebra mussels returned to activity in spring, they were competing with well-fed quagga mussel communities for already sparse resources. |
| 2.16. How important is the impact of the organism on biodiversity (e.g. decline in native species, changes in native species communities, hybridisation) currently in GB (include any past impact in your response)? | **minimal** | **very high** | It has not yet been found in GB. |
| 2.17. How important is the impact of the organism on biodiversity likely to be in the future in GB? | **massive** | **very high** | Quagga mussels will affect invaded ecosystems in a number of ways. Clearer waters resulting from massive filtration capacity (Cross et al., 2010) will lead to changes in algal diversity and abundance. Selective removal of green algae by dreissenids can reduce cyanobacteria from competition and lead to toxic blooms (MacIsaac et al., 1996). Grazing of algae by quagga mussels was estimated to match that of zooplankton in Lake Erie, USA (Zhang et al., 2010) and may explain the significant declines in biomass of cyclopoid copepods in Lake Ontario following mussel invasion (Bowen et al., 2011). The abundance of ciliates, *Daphnia* and rotifers reduced by 39, 40 45% respectively in Lake Michigan following dreissenid invasion (Kissman et al., 2010).<br><br>Nalepa et al. (2009) found that offshore benthic communities in Lake Michigan experienced a major shift following the invasion of Quagga mussels, with the replacement of native amphipods with the new mussel. A meta-analysis of benthic macroinvertebrate communities following Dreissena invasions (Ward & |

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| | | | Riciardi, 2007) suggests that following invasion, there is an increase in benthic density and taxonomic richness, but a reduced evenness. There were positive effects on densities of scrapers and predators (especially leeches, flatworms and mayflies), but reductions in large snails, spaeriid clams, unionid mussels and burrowing amphipods. Gammarid amphipods showed a positive response.<br><br>A decline in unionid mussels through Quagga mussel fouling has been reported by Schloeesser et al (2006). This is likely to pose a threat to the GB threatened mussel *Pseudanodonta complanata* (Sousa et al., 2011). |
| 2.18. How important is alteration of ecosystem function (e.g. habitat change, nutrient cycling, trophic interactions) caused by the organism currently in GB (include any past impact in your response)? | **minimal** | **very high** | It has not yet been found in GB. |
| 2.19. How important is alteration of ecosystem function (e.g. habitat change, nutrient cycling, trophic interactions) caused by the organism likely to be in GB in the future? | **massive** | **very high** | Their considerable filtration capacity drives systems towards a clearer state, thus typically increasing macrophyte growth (MacIsaac, 1996). However, accumulation of dead shell material on the lake bed can inhibit the growth of macroalgae such as *Cladophora* (Ward & MacIsaac, 2010). Biodeposition of faeces and psuedofaeces can change the benthos, and Cross et al. (2010) estimated that 1.51 x $10^{12}$ quagga mussels in Lake Mead, USA, would reduce the concentration of food particles in suspension by 50%, and therefore would have considerable impact on nutrient cycling. Excretion by Quagga mussels in Lake Erie was found to have a major deleterious effect on the ecosystem, with excretion driving an increase in phosphorus availability in the bottom water (Zhang et al., 2010). Higgins et al. (2011) found that chlorophyll a |

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| | | | declined by 40-45% within invaded lakes, and that total phosphorus in the water column dropped significantly in stratified systems.<br><br>Higgins & Vander Zanden (2010) performed a meta-analysis of the ecosystem impacts of dreissenid mussels in North America and Eurasia. They found that greatest impacts on algae (-35% to -78%) and zooplankton (-40 to 77%) occurred within rivers, followed by littoral and then pelagic regions of lakes. In contrast, benthic energy pathways within littoral habitat of lakes and rivers showed dramatic increases in mean benthic algal and macrophyte biomass (+170 to +180%), sediment-associated bacteria (+2000%) and non-dreissenid zoobenthic biomass (+160 to +210%). |
| 2.20. How important is decline in conservation status (e.g. sites of nature conservation value, WFD classification) caused by the organism currently in GB? | **minimal** | **very high** | It has not yet been found in GB. |
| 2.21. How important is decline in conservation status (e.g. sites of nature conservation value, WFD classification) caused by the organism likely to be in the future in GB? | **major** | **high** | The risk would be greater had Zebra mussels not already established in GB. Quagga mussels are likely to replace this impact in some systems. However, we would predict major ecological shifts in many GB systems, with a likely decline in threatened bivalves and large gastropods. The arrival of a new invasive species into some otherwise uninvaded systems may have implications for WFD classifications. |
| 2.22. How important is it that genetic traits of the organism could be carried to other species, modifying their genetic nature and making their economic, environmental or social effects more serious? | **minimal** | **high** | There is some evidence that Quagga mussels may hybridise with Zebra mussels (Voroshilova et al, 2010, but see Spidle et al., 1995), but there is no evidence that such hybrids are common or would present a novel invasive nuisance. |

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| 2.23. How important is social, human health or other harm (not directly included in economic and environmental categories) caused by the organism within its existing geographic range? | **minor** | **medium** | Cyanobacterial blooms can create a risk to human health and livestock. Shells can cause cuts in recreational areas. Dreissenids can concentrate human pathogens and disease, but are unlikely to pose an increased health risk (Frances Lucy, personal communication). |
| 2.24. How important is the impact of the organism as food, a host, a symbiont or a vector for other damaging organisms (e.g. diseases)? | **moderate** | **medium** | There is a risk of Quagga mussels contributing to invasional meltdown scenarios. This may increase the likelihood of other non-native species establishing and creating a nuisance. Quagga mussels, for instance, will provide suitable substrate for the killer shrimp (Madgwick & Aldridge, 2011) |
| 2.25. How important might other impacts not already covered by previous questions be resulting from introduction of the organism? (specify in the comment box) | **N/A** | **N/A** | |
| 2.26. 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 GB? | **major** | **very high** | We would not see the existing British biota to regulate the invasion of Quagga mussels to any great extent. |
| 2.27. Indicate any parts of GB where economic, environmental and social impacts are particularly likely to occur (provide as much detail as possible). [text + map if possible] | | **high** | Throughout the invasive range. |

| **RISK SUMMARIES** | | | |
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| | **RESPONSE** | **CONFIDENCE** | **COMMENT** |
| **Summarise Entry** | **very likely** | **very high** | Quagga mussels are well established in The Rhine and there are a number of uncontrolled vectors and pathways that will bring it to GB. |
| **Summarise Establishment** | **very likely** | **very high** | There is a strong bioclimatic and biotic similarity between much of GB and the invaded freshwaters of The Netherlands. |
| **Summarise Spread** | **rapid** | **high** | The track record of Zebra mussels suggest that spread will be relatively fast and widespread. Veligers can disperse downstream very rapidly. Association with human-mediated transport will facilitate upstream and overland salutatory dispersal. |
| **Summarise Impact** | **major** | **very high** | Major ecosystem shifts are expected. The risk would be assessed as massive had Zebra mussels not already made this contribution. However, it is likely that Quagga mussels have different impacts , reach different densities and inhabit a different range of habitats. |
| **Conclusion of the risk assessment** | **high** | **very high** | |

Additional questions are on the following page ...

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| **ADDITIONAL QUESTIONS - CLIMATE CHANGE** | | | |
| 3.1. What aspects of climate change, if any, are most likely to affect the risk assessment for this organism? [text] | | **high** | While no predictions specific to GB have been made for quagga mussels, Gallardo & Aldridge (unpublished) suggest that under a predicted 2050 climate projection a 40% range expansion is expected for the zebra mussel across Europe. As such, we might expect that a warming climate in GB will facilitate further spread of quagga mussels, especially northwards. In the southwestern U.S. where waters are warm, quagga mussels reproduce year round thereby producing several cohorts annually. Consequently, as climate warming occurs, the reproductive potential of drieissenids increases. |
| 3.2. What is the likely timeframe for such changes? | **40 years** | **medium** | 40 years |
| 3.3. What aspects of the risk assessment are most likely to change as a result of climate change? [text] | | **medium** | Range expansion and possible competitive advantage over native species which are less well suited to the changing environment. |
| **ADDITIONAL QUESTIONS - RESEARCH** | | | |
| 4.1. If there is any research that would significantly strengthen confidence in the risk assessment please summarise this here. [text] | | **very high** | 1. We would benefit from some models of spread, combining bioclimatic factors with water chemistry parameters. This will help to focus monitoring efforts and to better quantify economic and ecological risk.<br>2. A survey of successful and failed control and containment strategies would be worthwhile so that we are best prepared for the species' arrival, without trying out fruitless methodologies<br>3. Models are needed to include climate change scenarios so that section 3 can be completed. |

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