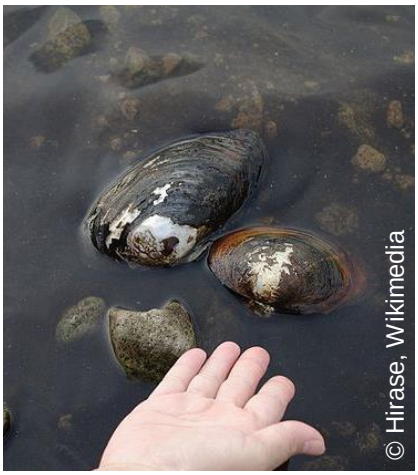
RISK ASSESSMENT SUMMARY SHEET

Chinese pond mussel (*Sinanodonta woodiana*)

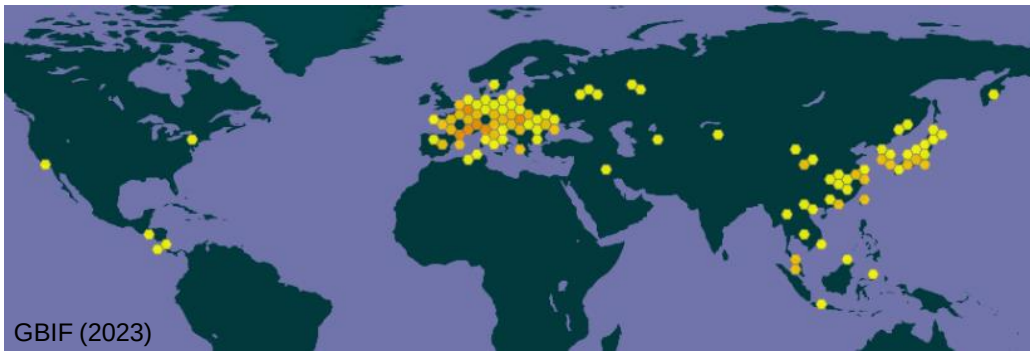


- A freshwater unionid mussel from south-east Asia that can reach sizes of up to 30 cm and an age of 12–14 years.
- Its larvae parasitise fish gills and one of its main pathway of introduction and spread is with fish movements.
- Widely introduced throughout Europe, with non-native populations elsewhere including southern Asia, northern Africa and the USA.
- Not currently established in GB; however, it has established in Europe under similar conditions to those found in GB.

History in GB

Not present in GB. The nearest populations are in Europe where this species was first introduced in Romania in 1979 and rapidly spread across much of Europe. It is currently recorded from at least 22 European countries.

Global Distribution



Native to Southeast Asia (Yangtze basin, China).

Not present in GB.

Impacts

Economic (minor, low confidence)

- If the species becomes established and widespread, it may cause changes to water quality possibly leading to reduced food availability for native species, as has been seen with *Dreissena.*

Environmental (major, medium confidence)

- Often achieved high biomass causing impacts to native species and ecosystem functions. High filtration capacity diverts biomass and nutrients from the water column to the sediment, changing nutrient cycling and water quality. Likely to reduce bivalve diversity in invaded systems and may impact on planktonic species and fish.

Social (minimal, medium confidence)

- None known.

Introduction pathway

Multiple potential pathways, the most likely of which are trade in freshwater fish, aquatic plants, but also contamination of recreational equipment, boats and as live bait.

Spread pathway

Natural (high, medium confidence): the species has high capacity to spread between connected water bodies, through the movement of free-living glochidia larvae and/or infected fish.

Human (major, medium confidence): in other European countries, spread between isolated water bodies has been facilitated by movements of fish.

Summary

	Response	Confidence
Entry	MODERATELY LIKELY	HIGH
Establishment	VERY LIKELY	HIGH
Spread	RAPID	HIGH
Impact	MAJOR	MEDIUM
Overall risk	HIGH	HIGH

GB NON-NATIVE ORGANISM RISK ASSESSMENT SCHEME

Name of organism: Chinese pond mussel, *Sinanodonta woodiana*
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Risk Assessment Area: Great Britain
Version: Draft 1 (Mar 2023), Peer review (May 2023), NNRAF 1 (Jun 2023), Draft 2 (Sep 2023), NNRAF 2 (Oct 2023), Draft 3 (Oct 2023)
Signed off by NNRAF: October 2023
Approved by GB Committee: January 2024
Placed on NNSS website: January 2024

What is the principal reason for performing the Risk Assessment?

The GB Committee for non-native species is considering whether to add this species to the list of species of special concern. This species was selected for consideration following horizon scanning[1] that identified it as one of the top 20 non-native species that pose a threat to biodiversity in Great Britain.

[1] https://www.nonnativespecies.org/assets/Document-repository/Horizon_scanning_short_report_2019-2.pdf

SECTION A – Organism Information	
Stage 1. Organism Information	**RESPONSE**
1. Identify the organism. Is it clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?	Chinese pond mussel, *Sinanodonta woodiana*. Yes, this species is generally recognised as a single entity within its invaded range within Europe. However, a number of synonyms exist within its native range and the taxonomy has not been resolved, meaning that it is regarded as the *Sinanodonta* species complex. According to Kondakov et al. (2018) the *Sinanodonta woodiana* species complex comprises at least six distinct biological species: *S. cf. gibba* (= temperate invasive lineage), *S. cf. woodiana* (=tropical invasive lineage), *S. schrenkii* (= *S. amurensis*), *S. ovata*, *S. jourdyi*, and *S. lucida*, and two phylogenetic lineages with uncertain taxonomic names. Unionidae are distinguished by a complex life cycle, which includes a brief, obligatory, larval stage which is ecto-parasitic on fish. Sperm is ejected into the water column by adult males and taken into the female's mantle cavity through the inhalant aperture. Fertilised eggs move from the mollusc's gonads to the gills where they further ripen and develop into glochidia, the first larval stage. Mature glochidia are released by the female and attach to the gills, fins, or skin of a host fish. A cyst is quickly formed around the glochidium. The offspring remain on the fish for some time before they metamorphose and fall off as free-living juvenile mussels. Generation time of *S. woodiana* is typically 2–5 years (Chen, Liu, Su, & Yang, 2015).
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)	NA
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?	NA
5. Where is the organism native?	Southeast Asia (Yangtze basin, China). According to Boltov et al. (2020) *S. woodiana* is invasive in the Amur basin, but other authors (e.g. Popa et al., 2007) include this region within the native range. The lineage that has invaded Europe is thought to originate from the Yangtze basin (Konečný et al., 2018; Kondakov et al., 2018, 2020). The native range in Indochina is unclear and may be confused by synonyms (Cummins,2011).
6. What is the global distribution of the organism (excluding the risk assessment area)?	Europe (**Austria**, Belgium, Bulgaria, **Croatia**, **Czechia**, **France**, **Germany**, Greece, **Hungary**, **Italy**, Kosovo, Moldova, Netherlands, **Poland**, **Romania**, Russia, **Serbia**, **Slovenia**, **Slovakia**, Spain, Sweden, Switzerland, Ukraine: countries with widespread records in bold), Russia, Iraq, Uzbekistan, Kazakhstan, North Africa, Southeast Asia, Australasia, USA, El Salvador, Costa Rica, Dominican Republic. The *Sinanodonta* species complex has been documented in the Dominican Republic and Costa Rica (Watters, 1997). Bogan et al. (2021) report the species in Iraq. It has also been recorded in North Africa (Morocco and Algeria). In Europe, *Sinanodonta woodiana* is the most widely introduced unionid mussel (Pou-Rovira et al., 2009). It was found first in Romania in 1979 (Sárkány-Kiss, 1986) and rapidly spread through Europe (Sárkány-Kiss, 1986; Popa et al., 2007; Cappelletti et al., 2009; Pou-Rovira et al., 2009). Current records on GBIF/iNaturalist include 22 European countries. It was also recorded in Moldova in 2003 (Munjiu et al., 2020) and Montenegro in 2012 (Tomović et al., 2013).
7. What is the distribution of the organism in the risk assessment area?	Absent
8. Is the organism known to be invasive (i.e. to threaten organisms, habitats or ecosystems) anywhere in the world?	Yes Expanded upon in the relevant sections.

9. Describe any known socio-economic benefits of the organism in the risk assessment area.	None The species is not present in the Risk Assessment area.

SECTION B – Detailed assessment

PROBABILITY OF ENTRY

Important instructions:

- Entry is the introduction of an organism into the risk assessment area. Not to be confused with spread, the movement of an organism within the risk assessment area.
- For organisms which are already present in the risk assessment area, 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.

QUESTION	RESPONSE	CONFIDENCE	COMMENT
1.1. How many active pathways are relevant to the potential entry of this organism? (If there are no active pathways or potential future pathways respond N/A and move to the Establishment section)	few	medium	i. Trade in freshwater fish, which can transport the glochidia larvae of the mussel, is the main pathway of spread into Europe (Watters, 1997). Although the importation of live fish to GB for release into the wild is regulated, it is likely that the species will evade detection. Introduction of adults as a contaminant with freshwater fish via the aquaculture/aquarium trade is less likely. ii. Trade in aquatic plants may introduce the species as a contaminant, where small juvenile mussels may be overlooked in the growth medium of aquatic plants. This pathway is regulated by the Animal and Plant Health Agency. iii. Contamination of recreational equipment and boats by small juvenile mussels is possible as other freshwater INNS are likely to have been introduced into GB via this pathway. iv. Import as live bait is possible as the species has been documented to travel via this pathway in Europe. v. Direct stocking is unlikely as the importation of live non-native mussels to GB is regulated (authorisation is required from the Fish Health Inspectorate and, although import of *S. woodiana* is not explicitly prohibited, an additional permit is required to

			import non-native species). This pathway is considered of negligible likelihood and so is not assessed in detail here.
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. For each pathway answer questions 1.3 to 1.10 (copy and paste additional rows at the end of this section as necessary).	i. Trade in freshwater fish. ii. Trade in aquatic plants. iii. Contaminant of recreational equipment and boats. iv. Import as live bait.		
Pathway name:	i. Trade in freshwater fish		
i.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)?	accidental	very high	This has been the main pathway of entry into and movement within European countries (Watters, 1997) and into the USA. Most (initial) records are from stocked fish ponds and lakes. There are records of deliberate introduction of the species to improve water quality (e.g. Urbańska et al., 2021), but these are rare.
i.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? Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place.	very likely	high	Glochidia larvae of *S. woodiana* are parasitic on the gills of fish. The species is a broad host generalist, which can complete its development on a wide range of both native and non-native fish species from a variety of families, including *Barbus barbus*, *Carassius gibelio*, *Ctenopharyngodon idella*, *Cyprinus carpio*, *Gasterosteus aculeatus*, *Gobio gobio*, *Leucaspius delineates*, *Leuciscus cephalus*, *Leuciscus idus*, *Perca fluviatilis*, *Pseudorasbora parva*, *Rhodeus amarus* and *Rutilus rutilus*, *Salmo trutta* (Douda et al., 2012; Huber & Geist 2019), and suspected *Aristichthys nobilis*, *Carassius auratus*, *Gambusia affinis*, *Hypophthalmichthys molitrix* and *Oreochromis niloticus* (Watters 1997).

			If the species is present in the source of fish imported into GB, there is the possibility that they may have been infected with glochidia larvae before starting the journey. The species is established in aquaculture facilities in Europe and in its native range (He & Zhang, 2013). As glochidia of *S. woodiana* can infect individual fish at high densities (10 - 2000 per individual: Douda et al., 2012; Huber & Geist 2019), there is the potential for large numbers of individuals to be transferred via this pathway.
i.1.5. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.	very likely	very high	This pathway requires the transfer of live fish, thus providing ideal conditions for the survival of the species along the pathway. Average duration of attachment of glochidia to host fish is 26 days at 16 °C Huber & Geist 2019) and 7−10 days at 20-22 °C (Douda et al. 2012) but glochidia have been recorded attached to the host for up to 61 days post infection (Huber & Geist 2019). Thus, the species could remain with the host through the entire transport process. Any juveniles released from the host fish would be able to survive in the conditions used to transport fish. This pathway involves the larval stage of the species' life-cycle: multiplication is not possible.
i.1.6. How likely is the organism to survive existing management practices during passage along the pathway?	likely	medium	The only management practice likely to influence the survival of *S. woodiana* is the detection of infection and destruction of the host fish. The importation of live fish to GB for release into the wild is regulated. Health certification of live fish imported into the UK is required under the Aquatic Animal Health (England and Wales) Regulations 2009 (SI 2009/463) and regulated by the Fish Health Inspectorate (Cefas). Health checks comprise assessments of notifiable diseases. Similarly release of fish to the wild requires a permit from the appropriate regulatory authority (e.g. Environment Agency in England), which involves a health check for diseases and parasites.Environment Agency health checks do not cover listed diseases as they are the responsibility of Cefas.

			Any unhealthy fish would be refused entry. However, *S. woodiana* is not included in the diseases listed in Annex 1A of Commission Regulation (EC) No 1251/2008 and health checks may not be alert to the risk presented by this species. Encysted glochida larvae can be identified using molecular techniques (Zieritz et al. 2012). Data on the volume of live fish entering the UK are held by Cefas. Aquaculture in the UK is dominated by production of salmonids, but cyprinids supply the economically important freshwater recreational angling sector (Tidbury et al., 2020). Cyprinid fish are commonly moved from farms to fisheries, and between fisheries for restocking (Tidbury et al., 2020). The ornamental fish sector imports 894,748 kg of live fish; 82% are freshwater fish (OATA, 2023). Czechia is the fifth most important source by value (OATA, 2023). Although cold water fish species (such as goldfish and carp) imported into the UK should not be stocked into recreational fisheries or the wild (without appropriate consent from the competent authorities), it is known that illegal stockings of such fish occur frequently (Copp et al., 2005) and the high number of countries and quantities imported mean that the potential for introducing fish infected with parasites (such as *S. woodiana*) is high (Tidbury et al., 2020).
i.1.7. How likely is the organism to enter the risk assessment area undetected?	likely	medium	Inspection of fish gills for glochidia requires the fish to be sacrificed: infected fish do not display obvious symptoms (Douda et al 2012). Only some of the fish being imported are inspected in a way that would detect *S.woodiana* infection. It is likely that some infected individuals may escape detection, particularly where infection rates are low. Illegal stockings of imported fish occur frequently (Copp et al., 2005) and are not subject to the usual checks.
i.1.8. How likely is the organism to arrive during the months of the year most appropriate for establishment?	very likely	high	It is highly likely that the organism would arrive following this pathway at a suitable time of year for establishment. If infected fish escape detection, any glochidia will remain with their host until they are ready to establish.

			In a population of *S. woodiana* in Czechia, mature glochidia were seen to occur in female mussels April-September (Douda et al. 2012). All months of the year are suitable for establishment of adults and juveniles (Chen et al., 2015).
i.1.9. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	very likely	high	Transfer of live fish is likely to introduce the species directly into suitable habitat. Average duration of attachment to maturity is 26 days at 16 °C Huber & Geist 2019) and 7−10 days at 20-22 °C (Douda et al. 2012) but glochidia have been recorded attached to the host for up to 61 days post infection (Huber & Geist 2019).
i.1.10. Estimate the overall likelihood of entry into the risk assessment area based on this pathway?	likely	high	This has been the main pathway of spread of the species. There is a high probability that fish infected with glochidia will not be detected. Individual fish can be infected by large numbers of larvae (up to 2,000 per fish recorded).
Pathway name:	ii. Trade in aquatic plants		
ii.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)?	accidental	low	Juvenile mussels are less than 1mm in size when released from the host fish, and are still small (<10 mm) at 60 days (Chen et al., 2015). Such recently deposited juveniles are likely to be easily overlooked. If fish infected with glochidia larvae are present in the source nursery, there is a risk that juveniles may be present in the growth medium of aquatic plants imported through the horticultural trade.
ii.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? Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place.	moderately likely	medium	Individual fish are frequently infected with many glochidia (10 - 2000 per individual: Douda et al., 2012; Huber & Geist 2019), such that, if an infected fish is present in the culture facility, high numbers of juveniles may be released and enter the growth medium at the same time. Whilst high densities of individuals are more likely to be noticed, the risk remains that they may be overlooked, or misidentified as native species. The import of pond plants with rooting medium (e.g. water lilies, etc.) presents the greatest risk, with the import of bare rooted plants likely to present a lower risk, however, there is still the potential for small juveniles to be overlooked if present.

ii.1.5. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.	very likely	very high	Transport conditions for aquatic/pond plants in the horticultural trade provides ideal conditions for the survival of aquatic species along the pathway (Kerr, Brousseau & Muschett, 2005). The import of pond plants with rooting medium presents the greatest risk, with the import of bare rooted plants likely to present a lower risk, however, there is still the potential for small juveniles to be overlooked if present.
ii.1.6. How likely is the organism to survive existing management practices during passage along the pathway?	likely	high	The importation of plants and plant products to GB is regulated, where a phytosanitary certificate is required before entry, which includes confirmation that the consignment has been officially inspected and is free from quarantine pests and diseases. Nevertheless, as *S.woodiana* is not on the list of quarantine pests and diseases there is high likelihood that any individuals present would not be detected. The growth of on-line peer-to-peer sales presents a considerable risk as they can avoid such inspections (Olden, Whattam & Wood, 2021).
ii.1.7. How likely is the organism to enter the risk assessment area undetected?	moderately likely	high	It is likely that young juveniles in plant growth medium may escape detection, especially where densities are low or juveniles small.
ii.1.8. How likely is the organism to arrive during the months of the year most appropriate for establishment?	very likely	high	If juveniles are transported in plant growth medium escape detection, they will establish readily in sites where planted.
ii.1.9. How likely is the organism to be able to transfer	very likely	high	Cold water aquatic plants are likely to be planted directly into suitable habitat and introduce the species there.

from the pathway to a suitable habitat or host?			
ii.1.10. Estimate the overall likelihood of entry into the risk assessment area based on this pathway?	moderately likely	high	Young juveniles are small, and easily overlooked or misidentified. Current plant health checks do not include *S. woodiana*. Any juveniles present in plant growth medium, particularly of pond plants, are likely to evade detection.
Pathway name:	iii. Contaminant of recreational equipment and boats.		
iii.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)?	accidental	high	Many freshwater invasive species are introduced by accident as a contaminant of recreational equipment such as fishing gear, wetsuits, boats and boat trailers. However, there are no known records of *S. woodiana* being moved within this pathway.
iii.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? Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place.	very unlikely	low	Freshwater species can be transported within water that is carried in the bottoms of boats and canoes or the bilge water of boat engines. The most likely taxa to be transported along this pathway are those with planktonic larvae, or those that are free-swimming in the water column. Whilst glochidia larvae of *S. woodiana* are free living, they must attach to host fish to complete development. No data are available on the duration of the free living stage. Whilst adults and juveniles are benthic, it is possible that small juveniles may be entrained in bilge water or other water/mud carried by watercraft. Therefore, it is considered that few individuals will pass along this pathway, although, as this pathway has not been investigated, confidence is low.
iii.1.5. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)?	very likely	high	While no studies have been conducted specifically on *S. woodiana*, it is well known that freshwater mussels can survive prolonged periods out of water. Holland (1991) reports that the North American mussel *Anodonta (Pyganodon) grandis*, which is morphologically similar to *S. woodiana*, can survive out of water from 1.75 to 144.5 days depending on temperature and humidity. A thicker shelled species, *Uniomerus tetralasmus* survived up to 580 days in air. The survival of juveniles out of water remains unknown.

Subnote: In your comment consider whether the organism could multiply along the pathway.			
iii.1.6. How likely is the organism to survive existing management practices during passage along the pathway?	very likely	high	As there are no management practices that would specifically target this species the assessment remains the same as above.
iii.1.7. How likely is the organism to enter the risk assessment area undetected?	very likely	medium	Juvenile mussels are less than 1mm in size when released from the host fish, and are still small (<10 mm) at 60 days (Chen et al., 2015) and so as contaminants of equipment would be very likely to escape detection. Adult mussels could be wrongly identified as the superficially similar native swan mussel, *Anodonta cygnea*, to the untrained eye (Kileen Aldridge & Oliver, 2004).
iii.1.8. How likely is the organism to arrive during the months of the year most appropriate for establishment?	likely	high	In a population of *S. woodiana* in Czechia, mature glochidia were seen to occur in female mussels April-September (Douda et al. 2012). All months of the year are suitable for establishment of adults and juveniles (Chen et al., 2015).
iii.1.9. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	very likely	high	Contaminated recreational equipment, such as fishing gear, wetsuits, boats and boat trailers, is likely to be moved to suitable habitat, facilitating transfer.
iii.1.10. Estimate the overall likelihood of entry into the risk assessment area based on this pathway?	unlikely	low	Transfer via this pathway would be restricted to adults or juveniles. Therefore, it is considered that few individuals will pass along this pathway although confidence is low, as this pathway has not been investigated.
Pathway name:	iv. Import as live bait		

iv. 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)?	intentional	very high	Lajtner & Crnčan (2011) reported that sports anglers bring bivalves including *S. woodiana* to Vrana Lake from elsewhere in Croatia for use as bait. Empty shells have been found on the shore.
iv. 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? Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place.	very unlikely	high	Due to the volume of equipment, anglers are likely to move by road between eastern Europe and GB. This is considered an important, but poorly appreciated pathway for introduction of invasive species (W. Solarz, personal communication). It is likely that *S. woodiana* would be live if transported via this pathway. However, it is unlikely that large numbers of live mussels would be transported along this pathway.
iv. 1.5. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.	very likely	high	Freshwater unionid mussels can survive for prolonged periods (days) out of water. If they are transported as bait, they are likely to be kept alive intentionally. The mussels would not be able to reproduce during such a journey as they depend on host fish to complete their life history.
iv.1.6. How likely is the organism to survive existing management practices during passage along the pathway?	very likely	high	Live bait is very unlikely to be disclosed at border controls. There are no management practices that would specifically target this species.

iv.1.7. How likely is the organism to enter the risk assessment area undetected?	moderately likely	medium	(as above).
iv.1.8. How likely is the organism to arrive during the months of the year most appropriate for establishment?	likely	high	Likely to be transported as adults, which would have a high chance of survival if released live in any month. Angling tourists most likely to travel during warmer months.
iv.1.9. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	moderately likely	medium	Any mussels used as bait would be killed in the process, but any unwanted live individuals released into recipient water bodies have a high chance of survival.
iv.1.10. Estimate the overall likelihood of entry into the risk assessment area based on this pathway?	unlikely	medium	There is evidence that the pathway exists in Europe (Tomovic et al., 2013). There is anecdotal evidence that the pathway exists for transfer to GB (W. Solarz, personal communication) and the mussels have the capacity to survive the journey. However, it is unlikely that large numbers of live mussels would be transported along this pathway.

End of pathway assessment, repeat as necessary.			
1.11. Estimate the overall likelihood of entry into the risk assessment area based on all pathways (comment on the key issues that lead to this conclusion).	likely	high	The species is widespread in Europe. The only management practice likely to influence the entry of *S. woodiana* is the detection and destruction of larvae/juveniles on materials imported into GB, particularly fish that are infected with glochidia.

PROBABILITY OF ESTABLISHMENT

Important instructions:

- For organisms which are already well established in the risk assessment area, only complete questions 1.15, 1.21 and 1.28 then move onto the spread section. If uncertain, check with the Non-native Species Secretariat.

QUESTION	RESPONSE	CONFIDENCE	COMMENT
1.12. How likely is it that the organism will be able to establish in the risk assessment area based on the similarity between climatic conditions in the risk assessment area and the organism's current distribution?	very likely	high	Whilst the species is regarded as thermophilic, early occurrences in Europe were often affected by discharges of warmed water, e.g. from power stations (Kraszewski, 2007; Bespalaya et al., 2018; Kondakov et al., 2020). However, there is evidence that the species has become cold-adapted in Europe (Konečný et al., 2018) and persists in Poland under conditions similar to those in GB (Urbańska et al., 2021).
1.13. How likely is it that the organism will be able to establish in the risk assessment area based on the similarity between other abiotic conditions in the risk assessment area and the organism's current distribution?	very likely	very high	In invaded sites in Europe, the species coexists with similar Unionid species that occur in GB (*Anadonta anatina, A. cygnea, Unio pictorum, U. tumidus*), giving high confidence that suitable abiotic conditions exist in GB.
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 the risk assessment area? Subnote: gardens are not considered protected conditions	very likely	high	The species is established in aquaculture facilities in Europe and in its native range (He & Zhang, 2013). Aquaculture and the aquarium trade are important components in the main pathway of spread in Europe and elsewhere.
1.15. How widespread are habitats or species necessary for the survival, development and	widespread	very high	Standing and slow flowing freshwaters containing freshwater fish. The species can use a wide variety of fish species as hosts for larvae.

multiplication of the organism in the risk assessment area?			The species is tolerant of poor water quality: it is a filter feeder consuming planktonic algae (Chen et al., 2015). Thermal limits to survival and reproduction may exclude northern areas, but the species survives as far north as Sweden (Von Proschwitz, 2008) and Northern Poland (Urbańska et al., 2021). There is suggestion that the species may have become adapted to colder conditions in Europe (Konečný et al., 2018).
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 the risk assessment area?	Likely	high	Larvae of the species are parasitic on the gills of fish, but *S. woodiana* is a broad host generalist, which can complete its development on many host fish species (Watters, 1997; Douda et al., 2012; Huber & Geist 2019), more so than native species (Huber. & Geist, 2019).
1.17. How likely is it that establishment will occur despite competition from existing species in the risk assessment area?	very likely	high	The species appears to out-compete native European species of Unionid molluscs, including those native to GB (Urbańska et al., 2019, 2021; Geist et al., 2023)
1.18. How likely is it that establishment will occur despite predators, parasites or pathogens already present in the risk assessment area?	very likely	very high	Already established in northern Europe. The species appears less susceptible to predation than native European species, including those native to GB (Dobler & Geist, 2022)
1.19. How likely is the organism to establish despite existing management practices in the risk assessment area?	likely	medium	Regulation of fish movements may prevent establishment via this pathway, but it is likely that the species will evade detection in health checks. Unregulated movements of fish present a considerable risk. Health checks on imported aquatic/pond plants imported with growth medium are unlikely to detect the species.
1.20. How likely are management practices in the risk assessment area to facilitate establishment?	Unlikely	high	Transfer of fish infected with larvae is the greatest risk. The fish health inspectorate monitors fish movements to prevent transfer of disease. Whilst glochidia may be detected, identification of *S. woodiana* as opposed to native species

			may not occur. Genetic tools are available for identification of glochidia (Zieritz et al., 2012) but it is unclear if they are applied by the fish health inspectorate.
1.21. How likely is it that biological properties of the organism would allow it to survive eradication campaigns in the risk assessment area?	unlikely	high	Eradication of invasive bivalves using chemical and physical approaches are used in industrial settings with good effect (Sousa et al., 2014). The effectiveness of these techniques in natural settings is unknown.
1.22. How likely are the biological characteristics of the organism to facilitate its establishment?	likely	high	Adults of morphologically similar species can withstand prolonged periods out of water (Holland, 1991). *S. woodiana* is a broad host generalist, which can complete its development on many host fish species (Douda et al., 2012; Huber & Geist 2019; Watters 1997).
1.23. How likely is the capacity to spread of the organism to facilitate its establishment?	moderately likely	medium	The species has high capacity to spread between connected water bodies, through the movement of glochidia larvae attached to fish.
1.24. How likely is the adaptability of the organism to facilitate its establishment?	likely	medium	There is evidence that the species has already become cold-adapted in Europe (Konečný et al., 2018)
1.25. How likely is it that the organism could establish despite low genetic diversity in the founder population?	very likely	high	There appears to be limited diversity among the European populations (Konečný et al., 2018) yet the species is established in many countries.
1.26. Based on the history of invasion by this organism elsewhere in the world, how likely is to establish in the risk assessment area? (If possible, specify the instances in the comments box.)	likely	high	If propagules (adults, juveniles or fish infected with larvae) enter the country, it is likely that they will establish.
1.27. If the organism does not establish, then how likely is it that transient populations will continue to occur?	Unlikely	high	To date no populations have been detected in the risk assessment area.

Subnote: Red-eared Terrapin, a species which cannot re-produce in the risk assessment area but is established because of continual release, is an example of a transient species.			Completion of the life cycle in the risk assessment area if introduced is a high probability. Transient populations are not a feature of the spread in other European countries.
1.28. Estimate the overall likelihood of establishment (mention any key issues in the comment box).	very likely	high	Constraints on pathways into the area are the main restriction on establishment. It is likely that the species will evade detection on pathways into the risk assessment area. Individuals that arrive in the risk assessment area are highly likely to establish.

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
2.1. How important is the expected spread of this organism in the risk assessment area by natural means? (Please list and comment on the mechanisms for natural spread.)	major	medium	The species has high capacity to spread between connected water bodies, through the movement of free-living glochidia larvae and/or infected fish. The species has spread through the Danube and tributaries (Lajtner & Crnčan, 2007) and Germany (Dobler et al., 2022) by natural means. Although adults can crawl up to 10 m per day (Urbańska et al 2021), dispersal appears to occur mostly through the spread of larvae, largely through the movement of infected fish. Adults can produce a large number of offspring: Huber & Geist (2019) obtained 500,000 larvae from five individuals in one day. Individual fish are frequently infected with many glochidia (10 – 2,000 per individual: Douda et al., 2012; Huber & Geist 2019). The distance spread via glochidial larvae is dependent on the movement of fish. Larvae can remain with the fish for long periods (recorded up to 61 days: Huber & Geist 2019). The first record of the species in Europe was in Romanian fish farms in 1979. By 1999 it had spread through the lower Danube system (Romania, Hungary, Bulgaria, Moldova, Serbia, Croatia) and into other river catchments in the Balkans ((Paunovic et al. 2006; Lajtner & Crnčan, 2007), and as far as Germany by 2002 (Bössneck & Klingelhöfer, 2011). By 2020 it was widespread in Bavaria (Germany) with populations established in the Danube-Main Canal (Dobler et al., 2022).

2.2. How important is the expected spread of this organism in the risk assessment area by human assistance? (Please list and comment on the mechanisms for human-assisted spread.)	major	medium	Spread between isolated water bodies will largely require human assistance. In other European countries spread between isolated water bodies has been facilitated by movements of fish or live adults (Lajtner & Crnčan, 2007: Urbańska et al., 2021; Dobler et al., 2022)
2.3. Within the risk assessment area, how difficult would it be to contain the organism?	with some difficulty	low	Spread between connected water bodies would be difficult to contain as glochidia have good dispersal due to the movement of host fish: the species has spread rapidly through connected waterways in the Danube (Paunovic et al. 2006; Lajtner & Crnčan, 2007) and Germany (Dobler et al., 2022) though natural means. Spread from isolated water bodies could be contained by increased vigilance and biosecurity measures.
2.4. Based on the answers to questions on the potential for establishment and spread in the risk assessment area, define the area endangered by the organism.	Lowland rivers and lakes, England and Wales	medium	The majority of the site invaded in Europe are lowland rivers and lakes. There is a possibility that they could thrive in other areas if introduced to suitable habitats.
2.5. What proportion (%) of the area/habitat suitable for establishment (i.e. those parts of the risk assessment area where the species could establish), if any, has already been colonised by the organism?	0-10	very high	The species has not been recorded from the risk assessment area.
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	If introduced, the species will take time to spread. Dispersal appears to occur mostly through the spread of larvae. Although sexual maturity is achieved after one year, the number of offspring is related to size (Urbańska et al 2019), such that generation time of *S. woodiana* is typically 2–5 years (Chen et al., 2015). Within the next five years it is likely that any populations established will comprise young/immature individuals reducing the probability of spread from the initial point of introduction.
2.7. What other timeframe (in years) would be appropriate to estimate any significant further spread of the organism in the risk assessment	20	low	*S. woodiana* is spreading rapidly in Europe, increasing the likelihood of establishment in the assessment area and of repeat introductions.

area? (Please comment on why this timeframe is chosen.)			Generation time of *S. woodiana* is typically 2–5 years (Chen et al., 2015) which would delay the spread of populations once established, but larger, mature individuals are capable of producing many offspring (Chen et al., 2015; Douda et al., 2012; Huber & Geist 2019). Once established and matured, it is likely that the spread will be rapid, as has been seen in other European countries (Lajtner & Crnčan, 2007; Benkö-Kiss et al., 2013; Dobler et al., 2022), particularly through connected water bodies. The rate of spread of the species will be influenced by the initial points of introduction and how they are connected to other water bodies. If established in highly connected water bodies (e.g. the canal network) the rate of spread is likely to be rapid.
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?	0-10	low	The species is likely to still be early in the invasion process. The extent of spread of the species will be influenced by how the initial points of introduction are connected to other water bodies. If established in highly connected water bodies (e.g. the canal network) the extent of spread is likely to be wide.
2.9. Estimate the overall potential for future spread for this organism in the risk assessment area (using the comment box to indicate any key issues).	rapidly	high	*S. woodiana* has spread rapidly in other countries of Europe, particularly in highly connected water bodies (Paunovic et al. 2006; Lajtner & Crnčan, 2007; Benkö-Kiss et al., 2013; Dobler et al., 2022). Other invasive bivalves with similar habitat requirements (e.g. *Corbicula, Dreissena*) have spread within the risk assessment area.

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.
- 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).
- Note questions 2.10-2.14 relate to economic impact and 2.15-2.21 to environmental impact. Each set of questions starts with the impact elsewhere in the world, then considers impacts in the risk assessment area separating known impacts to date (i.e. past and current impacts) from potential future impacts. Key words are in bold for emphasis.

QUESTION	RESPONSE	CONFIDENCE	COMMENTS
2.10. How great is the economic loss caused by the organism within its existing geographic range **excluding the risk assessment area**, including the cost of any current management?	minor	medium	Main effects are changes to water clarity, often seen as an economic benefit, and changes to sediment structure (Sousa et al., 2014). In some instances, the species has been deliberately introduced due to its capacity to reduce phytoplankton in the water column (e.g. Urbańska et al., 2021), leading to reduced water treatment costs or increased recreational value. Possible effects on fish may occur through competition for food and parasitism (Douda et al., 2017). Whilst ecto-parasitism by glochidia does not necessarily cause detrimental effects on fish, high densities of glochidia can impair fish condition (Douda et al., 2017; Huber & Geist 2019), and may cause mortality of juvenile fish (Báskay et al., 1996), which could impact fisheries. Changes in water clarity could lead to reduced food availability, as has been seen with *Dreissena* (Rosell & Gibson, 2001; Maguire & Grey, 2006), and hence potential impacts on fisheries. The species does not tend to cause mechanical issues, and associated costs, through mass build up on water

			treatment/navigation structures as other invasive bivalves do (Sousa et al., 2014). Mass die off of bivalves can have negative effects on water quality, depleting the water of oxygen and potentially causing fish kills (McDowell & Sousa, 2019). Considered a food resource in Asia.
2.11. How great is the economic cost of the organism **currently** in the risk assessment area **excluding management** costs (include any past costs in your response)?	minimal	very high	The species is not established in GB.
2.12. How great is the economic cost of the organism likely to be **in the future** in the risk assessment area **excluding management** costs?	minor	low	If the species becomes established and widespread, it may cause changes to water quality possibly leading to reduced food availability for native species, as has been seen with *Dreissena* (Rosell & Gibson, 2001; Maguire & Grey, 2006), and potentially impacting fisheries. Such changes would be likely to cause a shift from planktonic to benthic fish species.
2.13. How great are the economic costs **associated with managing** this organism **currently** in the risk assessment area (include any past costs in your response)?	minimal	very high	The species is not established in GB.
2.14. How great are the economic costs **associated with managing** this organism likely to be **in the future** in the risk assessment area?	moderate	low	The species is spreading rapidly in Europe. Costs to reduce establishment of the species will be incurred through increased biosecurity for trade in fish and aquatic plants. Costs to control spread once established will include eradication and biosecurity costs. Eradication costs are likely to be high. Increased awareness of the species would benefit in preventing any spread associated with water sports. Existing biosecurity

			procedures are likely to be effective against this species, so additional costs would be limited.
2.15. How important is environmental harm caused by the organism within its existing geographic range **excluding the risk assessment area**?	moderate	medium	Can affect hydrology, biogeochemical cycling, and biotic interactions (Sousa et al., 2014). Appears to outcompete native Unionids in invaded areas (Benkö-Kiss et al., 2013; Urbańska et al., 2019; Dobler et al., 2022) and may affect reproduction of native species through reduced susceptibility of fish to infection by glochidia (Huber & Geist 2019). May impact fishes (Douda et al., 2017). Mass mortality can cause issues (McDowell & Sousa, 2019). Details of environmental harm in the invaded area are limited to effects on Unionids.
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 the risk assessment area (include any past impact in your response)?	minimal	very high	Not established in GB.
2.17. How important is the impact of the organism on biodiversity likely to be in the **future** in the risk assessment area?	moderate	medium	Can affect hydrology, biogeochemical cycling, and biotic interactions (Sousa et al., 2014). Appears to outcompete native Unionids (Benkö-Kiss et al., 2013; Urbańska et al., 2019; Dobler et al., 2022). May impact fishes (Douda et al., 2017). The species has a high filtration capacity and is likely to divert biomass and nutrients from the water column to the sediment, changing nutrient cycling and water quality (Dobler et al., 2022). The species is likely to reduce the diversity of bivalves in invaded systems. Impacts on other species are more difficult to predict (no reports of wider impacts are available), but are liklely to include negative impacts on native planktonic species (algae, zooplankton) and fish.

2.18. How important is alteration of ecosystem function (e.g. habitat change, nutrient cycling, trophic interactions), including losses to ecosystem services, caused by the organism **currently** in the risk assessment area (include any past impact in your response)?	minimal	very high	Not established in GB.
2.19. How important is alteration of ecosystem function (e.g. habitat change, nutrient cycling, trophic interactions), including losses to ecosystem services, caused by the organism likely to be in the risk assessment area in the **future**?	major	medium	The species has a high filtration capacity due to large size. This diverts biomass and nutrients from the water column to the sediment, changing nutrient cycling and water quality (Dobler et al., 2022). The species often achieves high biomass in invaded sites (Paunovic et al. 2006): Dobler et al. (2022) report a maximum of 3.3 kg m^{-2}. There is the potential that such high biomass cound be acheived in the assessment area under suitable conditions, with associated impacts on ecosystem functioning.
2.20. How important is decline in conservation status (e.g. sites of nature conservation value, WFD classification) caused by the organism **currently** in the risk assessment area?	minimal	very high	Not established 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 the risk assessment area?	moderate	low	Potential to alter planktonic and benthic fauna, directly through filter feeding, competition with other Unionids and indirectly through production of pseudofaeces (Benkö-Kiss et al., 2013; Urbańska et al., 2019; Dobler et al., 2022). Effects on smaller native freshwater bivalves (Sphaeriidae) not known. There may be some benefits through increased water clarity. High risk of negative impacts on *Pseudoanodonta complanata* (Rossmässler) as the species has similar habitat requirements. Low risk of negative impacts on *Margaritifera margaritifera* (L.) as the species has different habitat requirements: *S. woodiana*

			prefers nutrient rich, slow flowing water bodies with soft substrate. Effects on other freshwater bivalves of conservation importance, *Sphaerium solidum* (Normand), *Psidium pseudosphaerium* Favre and *P. tenuilineatum* Stelfox, are not known, but potentially at risk as they have similar habitat requirements.
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	very high	No indication of hybridisation
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?	minimal	medium	None known.
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)?	minimal	medium	None known.
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)	NA	very high	
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 the risk assessment area?	moderate	medium	Although predation pressure is generally low, *S.woodiana* is predated by Oystercatcher (*Haematopus ostralegus*), white-tailed eagle (*Haliaeetus albicilla*), wild boar (*Sus scrofa*), red fox (*Vulpes vulpes*), and otter (*Lutra lutra*) (Urbańska et al., 2013), *S. woodiana* is not particularly susceptible to predation, (Dobler & Geist, 2022).

2.27. Indicate any parts of the risk assessment area where economic, environmental and social impacts are particularly likely to occur (provide as much detail as possible).			
2.28. Estimate the overall impact of this organism in the risk assessment area (using the comment box to indicate any key issues).	major	medium	Competition with native Unionids, Changes to water and sediment quality, impacts on nutrient cycling. May be some benefits through increased water clarity.

RISK SUMMARIES			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	likely	high	The species is widespread in Europe. The only management practice likely to influence the entry of *S. woodiana* is the detection and destruction of larvae/juveniles on materials imported into GB, particularly fish that are infected with glochidia.
Summarise Establishment	very likely	high	Pathways of introduction are well connected to suitable habitat for establishment. Dispersal pathways involve larval/juvenile stages, potentially in large numbers.
Summarise Spread	rapidly	high	Spread has been rapid in other European countries. Rate of spread will depend on the extent to which the initial points of introduction are connected to other water bodies.
Summarise Impact	major	medium	Likely to cause changes in ecosystem functioning due to high filtration capacity.
Conclusion of the risk assessment	high	medium	

Additional questions are on the following page ...

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
3.1. What aspects of climate change, if any, are most likely to affect the risk assessment for this organism?	Warming	high	*Sinanodonta woodiana* survives at water temperatures up to 38°C and has a higher tolerance to thermal stress than the native European mussels (Bielen et al., 2016). The native range of the species includes habitats with higher temperature ranges than native European unionids (Kraszewski & Zdanowski, 2007), suggesting that climate warming may increase its competitive advantage. However, there is evidence that the species has already become thermally adapted to the European climate (Konečný et al., 2018).
3.2. What is the likely timeframe for such changes?	5 years	medium	Modest warming in Europe could move temperatures closer to the optimum for growth and reproduction of the species in its native range. However, adaptation to European climate may already have occurred (Konečný et al., 2018).
3.3. What aspects of the risk assessment are most likely to change as a result of climate change?	Spread	medium	Range may expand further north.
ADDITIONAL QUESTIONS - RESEARCH			
4.1. If there is any research that would significantly strengthen confidence in the risk assessment please summarise this here.	NA	NA	

Please provide a reference list on the following page ...

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