RISK ASSESSMENT SUMMARY SHEET

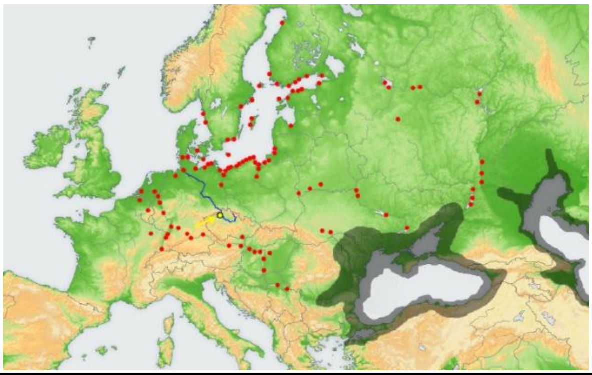
Round Goby (*Neogobius melanostomus*)

- A Ponto-Caspian fresh and brackish water goby that can be recognised by its prominent black spot on the first dorsal fin.
- Not yet recorded in GB but identified as a possible new arrival through horizon-scanning.
- Invasive in North America, Austria, Sweden, Baltic Sea basin and Netherlands.
- Adverse ecological effects reported, including reduced abundance of native fish and benthic organisms directly through predation as well as indirectly via competition for food and spawning habitat.

History in GB

Not yet recorded in GB.

Native Distribution



The grey areas show the native range (Black Sea, Caspian Sea, and Sea of Azov and tributaries).

Red dots show non-native range in Europe.

GB Distribution

No records from GB.

Impacts

Economic (major, low confidence)

- Impacts are probably the greatest where economically important predatory food fish are caught due to accumulation of contaminants in these piscivorous fish and because of possible high management costs.

Environmental (major, high confidence)

- Impact is expected in ecologically valuable river upper reaches with endangered native species.
- Round goby competition can lead to major declines and even extirpation of native benthic fishes and other species e.g. sculpin species (*Cottus gobio* and *C. perifretum*) in Europe.

Social (moderate, medium confidence)

- A transfer of contaminants to upper trophic levels by round goby may cause human health issues when the contaminated fish are eaten frequently.
- Impacts are most likely to occur at important angling waters, where round goby may deter anglers from fishing due to very frequent capture as by-catch.

Introduction pathway

Transport of both eggs and adults through hull fouling and ballast water. Also for use as live bait (illegally).

Spread pathway

Natural (moderate, high confidence): a relatively high proportion of migrants in streams facilitates fast spread rates, with estimates ranging from 500 m/year to up to 1–4 km/year in select areas.

Human (major, high confidence): Inland ships and yachts can disperse the round goby eggs, larvae. When anglers use round goby as live bait they can transfer them over long distances.

Summary

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

GB NON-NATIVE ORGANISM RISK ASSESSMENT SCHEME
Name of organism: *Neogobius melanostomus* – round goby **Author:** Hugo Verreycken, Research Institute for Nature and Forest, Flanders, Belgium **Risk Assessment Area:** Great Britain **Version:** Draft 1 (Nov 2022), NNRAF 1 (Dec 2022), Peer Review (Jan 2023), Draft 2 (Feb 2023), NNRAF 2 (Jun 2023), Draft 3 (Aug 2023) **Signed off by NNRAF:** June 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 assessment will form part of the evidence used to inform the Committee's decision. This species was selected for consideration following horizon scanning, in which this species was ranked in the top 10 threats to biodiversity because of its ability to cause declines in native fish populations and its predation of native invertebrates.

SECTION A – Organism Information

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. *Neogobius melanostomus* (Pallas, 1814). Round goby is a Ponto-Caspian fresh and brackish water goby that can be recognised from other Ponto-Caspian gobies by its prominent black spot on the first dorsal fin. The pelvic fins are fused into a scallop-shaped sucker. The body is brownish or olive in colour, with dark brown spots (reproducing males are almost completely black) (Kornis et al. 2012). The nostril tubes do not reach the upper lip (unlike the tubenose goby) and the body is fully scaled (unlike the racer goby). The bighead goby can be distinguished from round goby by its head that is wider than high, while for round goby width and height of the head are about the same (Kottelat & Freyhof 2007).	
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)	Yes. A rapid risk assessment for the RA area was produced for 3 Ponto-Caspian gobies (tubenose, racer and round goby) (Gozlan et al. 2019). A previous risk screening predicted round goby to pose a ‘High Risk’ of becoming invasive in England & Wales (Copp et al. 2009). RAs for round goby also exist for other areas e.g. the USA (U.S. Fish and Wildlife Service, 2019), Lake Simcoe, Ontario, Canada (Cudmore & Koops 2007), Belgium (Verreycken 2013), The Netherlands (rapid assessment by Spikmans et al. 2010).	
4. If there is an earlier risk assessment is it still entirely valid, or only partly valid?	Partially.	

	The rapid risk assessment by Gozlan (2019) is still valid but does not contain all the information for a full assessment. The other existing full risk assessments were not made for the risk assessment area (RA area), however, climate and habitats in the assessed areas are similar to the RA area.
5. Where is the organism native?	Eurasia including Black Sea, Caspian Sea, and Sea of Azov and tributaries. <ins>Countries:</ins> Azerbaijan; Bulgaria; Georgia; Iran, Kazakhstan; Moldova; Romania; Russian Federation; Turkey; Turkmenistan; Ukraine Pinchuk et al. (2003) and Kottelat & Freyhof (2007).
6. What is the global distribution of the organism (excluding the risk assessment area)?	Great Lakes in North America, large parts of Western, North and Central Europe. <ins>Countries:</ins> USA, Canada, Austria; Belgium; Bulgaria; Czech republic; Germany; Denmark; Estonia; Finland; France; Croatia; Hungary; Italy; Lithuania; Luxembourg; Latvia; Netherlands; Poland; Romania; Sweden; Slovakia. See Kornis et al. (2012) for North America and Verreycken (2019) for the EU. Distribution maps of round goby are available in e.g. Copp et al. (2005), Kottelat & Freyhof (2007), Buřič et al. (2015), Puntilla-Dodd et al. (2021, Baltic Sea only).
7. What is the distribution of the organism in the risk assessment area?	Not known to be present in the risk assessment area (Zięba et al. 2010, Godard et al. 2012). Also Roy et al. (2014) suggest the species is absent from the risk assessment area.
8. Is the organism known to be invasive (i.e. to threaten organisms, habitats or ecosystems) anywhere in the world?	Yes. Round goby is known to be invasive in virtually all the areas where it was introduced (see also Kornis et al. 2012; van Kessel et al. 2016; Janáč et al. 2019).
9. Describe any known socio-economic benefits of the organism in the risk assessment area.	Absent in the risk assessment area and no known benefits.

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)	none very few **few** moderate number many very many	low medium **high** very high	Godard et al. (2012) mention hull fouling as the most plausible introduction pathway for Great Britain but also ballast water, though as a less likely mechanism for GB. Bussmann & Burkhardt-Holm (2020) found evidence for hull fouling when they noticed several round goby specimens attached to boat hulls in the river Rhine. The survival of round goby during the Channel or North Sea crossing, however, remains very uncertain as no established populations are known to exist in oceanic salinities (Forsgren & Hanssen 2022). Karsiotis et al. (2012) conclude from their experiments that oceanic salinities appear fatal to the invasive round goby, which likely cannot withstand complete seawater ballast exchanges or oceanic habitats. Consignment contamination is put forward as a plausible pathway for two other Ponto-Caspian gobies by Godard et al. (2012) and could be a plausible pathway for round goby too. However, no other literature is available on this pathway for round goby and therefore deemed a very unlikely pathway, that is not dealt with in this RA. Natural dispersal from other invaded areas is not possible since there is no freshwater connection to mainland Europe, which makes dispersal from other infested areas impossible (Gordon Copp, pers. comm.). Dispersal by anglers after illegally using gobies as live bait is another possible pathway. Individual animals can detach from hooks and survive; surplus bait fish are sometimes

			released in the fishing water even though they were caught elsewhere (e.g. Lake Simcoe (Cudmore & Koops 2007)).
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).	- Hull fouling - Ballast water - Live bait		See 1.1.
Pathway name:	A. Hull fouling		
A1.3. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)? (If intentional, only answer questions 1.4, 1.9, 1.10, 1.11)	intentional **accidental**	low medium high **very high**	Hull fouling is an accidental vector since no intentional active human aid is involved here.
A1.4. How likely is it that large numbers of the organism will travel along this pathway from the	very unlikely unlikely **mod. likely** likely	low **medium** high very high	Eggs are sticky and may be attached to ship hulls (CABI fact sheet). This pathway was described in Corkum et al. (2004), Jude (1997) and Jude et al. (1992). Up to 10 000 eggs from four to six females may be present in a nest, and fertilisation and hatching rates are as high as 95% (Charlebois et al., 1997) so if the fertilised eggs survive the travel, large

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		numbers can be transported at one time. Beside transport of eggs through the hull fouling pathway, round goby may also stick to hulls as adults. Bussmann and Burkhardt-Holm (2020) report adult round gobies on ships hulls in the river Rhine in Basel. Up to 28 sightings in 45 minutes were witnessed on one boat. Round goby has fused pelvic fins that can be used as a sucker to stick to (smooth) surfaces e.g. boat hulls and rocks. the survival of the assessed species, however, is probably very low to nil due to the passing through full oceanic water with a salinity of 35 PS.
A1.5. 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 unlikely **unlikely** moderately likely likely very likely	low medium **high** very high	*Neogobius melanostomus* probably has a salinity tolerance <30 (Practical Salinity, PS) in oceanic (NaCl) waters (Kornis et al. 2012) thus survival during the crossing of the North Sea (mean salinity of 35) seems unlikely. Nevertheless, Godard et al. (2012) state that "North America and GB are similar in their geographical relation to Europe in the sense that they are separated by a marine barrier. The English Channel and the North Sea are much narrower than the Atlantic and easier to traverse. Therefore, it can be argued that if a species is able to invade across such an expanse of water as the Atlantic, then it is also likely to cross the English Channel or North Sea, especially considering the extensive network of freight vessels going between Northern Europe and GB". Reproduction during the passage is extremely unlikely because of extreme circumstances during the passage.
A1.6. How likely is the organism to survive existing management practices during passage along the pathway?	very unlikely **unlikely** moderately likely likely very likely	**low** medium high very high	For smaller vessels, the Check, Clean and Dry (GB NNSS) procedure may prevent introduction of organism on hulls. In case adult specimens would stick to the hull (Bussmann & Burkhardt-Holm 2020) and survive the passage of the North Sea, they would probably release in a harbour in the RA area before management practices could be applied.
A1.7. How likely is the organism to enter the risk assessment area undetected?	very unlikely unlikely moderately likely **likely** very likely	low medium **high** very high	A lump of eggs is very small and can be hidden on many places on a ship's hull, where it can stay easily unnoticed. Adult specimens would probably release before inspection and/or detection.

A1.8. How likely is the organism to arrive during the months of the year most appropriate for establishment?	very unlikely unlikely moderately likely **likely** very likely	low medium **high** very high	Boat and ship traffic occurs all year round but may be busier during the warmer months when many yachts travel to mainland Europe. Round goby is known to have a prolonged reproduction season with multiple spawning events from April to September and sometimes even later (Kornis et al. 2012).
A1.9. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	very unlikely unlikely moderately likely likely **very likely**	low medium **high** very high	Ships arrive in brackish to freshwater harbours where perfect habitats exist for round goby (Kornis et al. 2012). Round goby thrives well in man-made canals and adapted rivers with fortified banks with riprap and/or large boulders, and these habitats are typically present in or near arrival places for round goby. They typically spawn, feed and hide in hard substrata and are most abundant in rocky habitats (Kornis et al. 2012).
A1.10. Estimate the overall likelihood of entry into the risk assessment area based on this pathway?	very unlikely **unlikely** moderately likely likely very likely	low medium **high** very high	The survival of the assessed species is probably low to very low due to the passing through full oceanic water with a salinity of 35. Only a long-term acclimation to higher salinities (and with high mortality) a maximum salt tolerance of round goby was established at about 30 (Behrens et al. 2017).
End of pathway assessment, repeat as necessary.			
Pathway name:	B. Ballast water		
B1.3. 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 **accidental**	low medium high **very high**	Specimens of round goby (especially the nocturnally pelagic larvae) can be accidently taken in with the filling of ballast water (Kornis et al. 2012). This has recently also been shown for small watercraft motors (Bussmann et al. 2022).

(If intentional, only answer questions 1.4, 1.9, 1.10, 1.11)			
B1.4. 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 unlikely **moderately likely** likely very likely	low medium **high** very high	Round goby is known to have been introduced in North America and North and West Europe by ballast water of transoceanic ships from 1990 onwards (Kornis et al. 2012, Mombaerts et al. 2014, Buřič et al. 2015). Nocturnal ballast water take-up could easily result in the transport of thousands of juveniles at a time (Hayden & Miner 2009). In 2017 the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 (BWM Convention), entered into force globally, forcing ships to manage their ballast water. This regulation should prevent or at least diminish introductions through ballast water exchange. However, some routes and ships may be exempt from this regulation (Outinen et al. 2021). And in practice, new introductions via ballast water still occur, e.g. the recent find of the North American naked goby *Gobiosoma bosc* in Western Europe (Verreycken et al. 2019, Dodd et al. 2022). Godard et al. (2012), however, consider ballast water as a less likely mechanism for the RA area. Ballast water exchange is only permitted in UK ports if they have a ballast water reception facility. Otherwise, exchange must occur within designated ballast water exchange areas and there are none designated for the Irish Sea/Bristol Channel or the English Channel (Stacey Clarke, pers. comm.). However, exemptions from the BWM Convention are possible (see https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1003522/BW_-_FAQ_-_GOV.UK.pdf) leaving possibilities for round goby introductions.
B1.5. 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	very unlikely unlikely moderately likely likely **likely** very likely	low medium **high** very high	Multiplying of the organism along the pathway is very unlikely as many factors are needed to happen at the same time (presence of adult males and females, spawning event and fertilisation) which is very unlikely (Meunier et al. 2009, Sokolowska et al. 2015). Survival on the other hand is likely as this pathway was successful in many other regions. Night-time foraging suggests that *N. melanostomus* would be able to survive in dark ballast tanks for extended periods (Hayden & Miner 2009).

whether the organism could multiply along the pathway.			
B1.6. How likely is the organism to survive existing management practices during passage along the pathway?	very unlikely **unlikely** moderately likely likely very likely	low medium **high** very high	Stringent measures are in place for new vessels which should prevent introductions of non-native species in the future (www.imo.org). Older ships have less stringent measures to take (e.g. exchange of fresh ballast water in marine environment and vice versa) but in the RA area ballast water exchange is only permitted in UK ports if they have a ballast water reception facility. Otherwise, exchange must occur within designated ballast water exchange areas and there are none designated for the Irish Sea/Bristol Channel or the English Channel (Stacey Clarke, pers. comm.).
B1.7. How likely is the organism to enter the risk assessment area undetected?	very unlikely unlikely moderately likely **likely** very likely	low medium **high** very high	If round goby would arrive by ballast water, then it would go unnoticed until larger specimens would be found in the receiving waters, this happened also in the Laurentian Great Lakes (USA) (Vander Zanden et al. 2010).
B1.8. How likely is the organism to arrive during the months of the year most appropriate for establishment?	very unlikely unlikely moderately likely **likely** very likely	low medium **high** very high	Boat and ship traffic occurs all year round but may be busier during the warmer months when many yachts travel to mainland Europe. Round goby is known to have a prolonged reproduction season with multiple spawning events from April to September (Kornis et al. 2012) and even later.
B1.9. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	very unlikely unlikely moderately likely likely **very likely**	low medium **high** very high	Ships arrive in brackish to freshwater harbours where perfect habitats exist for round goby. Round goby thrives well in man-made canals and adapted rivers with fortified banks with riprap and/or large boulders. They typically spawn, feed and hide in hard substrata and are most abundant in rocky habitats (Kornis et al. 2012).
B1.10. Estimate the overall likelihood of entry into the risk assessment	very unlikely unlikely	low **medium** high	Ballast water was the main introduction pathway of round goby in many parts of its non-native range. However, more stringent measures (BWM Convention) entered into force globally on 8 September 2017. This should diminish the chance of introduction in the RA

area based on this pathway?	**moderately likely** likely very likely	very high	area (https://wwwcdn.imo.org/localresources/en/MediaCentre/HotTopics/Documents/BWM%20infographic_FINAL.pdf). Still, despite the new measures, new introductions via ballast water seem to continue (e.g. naked goby in Western Europe (Dodd et al. 2022)).
End of pathway assessment, repeat as necessary.			
Pathway name:	Live bait		
C1.3. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)? (If intentional, only answer questions 1.4, 1.9, 1.10, 1.11)	**intentional** accidental	low medium high **very high**	Round goby is (illegally) used in Europe and the US as live bait to catch large predatory fish species e.g. pikeperch (*Sander lucioperca*) (Jacobs & Hoedemakers 2013). The species may be transported to the RA area to use as live bait and detach from hooks or surplus bait fish may be released.
C1.4. 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** unlikely moderately likely likely very likely	low **medium** high very high	It would be relatively easy to transport (by car, van or boat) live specimens of round goby from mainland Europe to the RA area. It is unlikely, however, that large numbers are transported illegally. Unlike topmouth gudgeon and sunbleak, which arrived as stowaway species or contaminant in fish consignments (Zieba et al. 2010), round goby is seldom or not present in aquaculture ponds but in large canals and river systems, this means that round goby overseas introductions have to be intentionally planned by anglers. Most anglers will therefore probably confine to the use of already available live bait species in the RA area.

C1.9. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	very unlikely unlikely moderately likely **likely** very likely	low medium **high** very high	People who would make the effort of bringing live specimens of round goby from mainland Europe to the RA area would make sure the fish are transported in the best possible way and are kept in good condition until use.
C1.10. Estimate the overall likelihood of entry into the risk assessment area based on this pathway?	very unlikely **unlikely** moderately likely likely very likely	low **medium** high very high	No evidence could be found that live specimens of round goby are (illegally) transported from mainland Europe to the RA area.
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).	very unlikely unlikely **mod. likely** likely very likely	low **medium** high very high	Of the above-mentioned pathways, the ballast water pathway seems the most likely way for *N. melanostomus* to enter the RA area. However, the survival of round goby during the passage from mainland Europe to the RA area is probably extremely low (due to too high salinities). So despite the large number of daily shipping transports between Europe and the RA area, no single round goby was ever recorded in the RA area. Still, the 3 pathways together constitute many possibilities for the transport and possible introduction of round goby from mainland Europe to the RA area and the risk of entry is therefore estimated as moderately likely (with medium confidence).

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 unlikely unlikely moderately likely likely **very likely**	low medium high **very high**	*Neogobius melanostomus* has numerous established populations in Eurasia and North America over a wide range of climatic conditions (Kornis et al. 2012). It is established and widespread in Northwestern Europe (e.g. The Netherlands, Belgium, Germany, France, Denmark) (Froese & Pauly 2022) with similar climatic conditions as the RA area. Climatch (https://climatch.cp1.agriculture.gov.au/) indicates that the current European distribution of round goby best matches with the southeast of the RA area but overall scores 6, 7 and 8 prevail for the whole RA area.
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 unlikely unlikely moderately likely **likely** very likely	low medium high **very high**	Abiotic conditions in the RA area are similar to the organism's current distribution. Many other freshwater fish species occur both in the RA area and mainland Europe evidencing similar abiotic conditions.
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 unlikely **unlikely** moderately likely likely very likely	Low **medium** high very high	Only aquaculture facilities that use infested (i.e. invaded by round goby) surface water to fill their ponds may attain some round gobies in their facilities and even then establishment is unlikely since the optimal habitat of round goby will probably not be present. However, round goby can establish in both mud and rock habitats (Taraborelli et al. 2009)

1.15. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in the risk assessment area?	very isolated isolated moderately widespread widespread **ubiquitous**	low medium **high** very high	*Neogobius melanostomus* tolerate a wide range of habitat conditions, potentially contributing to its widespread success (Kornis et al. 2012). It is a benthic euryhaline species, inhabiting freshwaters of rivers and lakes to brackish polyhaline salinities. Artificial reefs (wave breakers), piers, rocky and stony areas are the most favourable habitat but they also occur on sandy bottoms (Sapota & Skóra, 2005). All these habitats are present in the RA area.
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?	**NA** very unlikely unlikely moderately likely likely very likely	low medium high **very high**	No other organisms required.
1.17. How likely is it that establishment will occur despite competition from existing species in the risk assessment area?	very unlikely unlikely moderately likely likely **very likely**	low medium high **very high**	Carman et al. (2006) indicate that many of the systems invaded by round goby contain highly diverse communities of native species. This statement is supported by many other authors e.g; Taraborelli et al. (2009), Gutowsky et al. (2011), van Kessel et al. (2016), Janáč et al. (2019), and Verreycken (unpublished data).
1.18. How likely is it that establishment will occur despite predators, parasites or pathogens already present in the risk assessment area?	very unlikely unlikely moderately likely likely **very likely**	low medium high **very high**	Establishment of round goby in mainland Europe (see e.g. van Kessel et al. 2016; Janáč et al. 2019) and North America (see Kornis et al. 2012) occurred in canals, lakes and large rivers where predators, parasites or pathogens were already present.
1.19. How likely is the organism to establish despite existing management practices in the risk assessment area?	very unlikely unlikely moderately likely **likely** very likely	low medium high **very high**	Once round goby arrives in the RA area, establishment is almost certain as was seen in many other invaded areas. Management of large, open waters to stop invasive species establishment is very difficult if not impossible (Britton et al. 2008, 2009; Verreycken 2019).

1.20. How likely are management practices in the risk assessment area to facilitate establishment?	very unlikely **unlikely** moderately likely likely very likely	low medium **high** very high	Management practices to stop invasion and/or establishment of an invasive species are not likely to facilitate establishment.
1.21. How likely is it that biological properties of the organism would allow it to survive eradication campaigns in the risk assessment area?	very unlikely unlikely **mod. likely** likely very likely	low **medium** high very high	Because of its benthic life style in between rocks, boulders and rip-rap (Erős et al. 2005), round goby is difficult to eradicate with mechanical methods such as fyke nets, gill nets, trawl nets. However, sustained trapping and removal of round goby adults and eggs can help to control the round goby population and keep it at a low density level (N'Guyen et al. 2018). Round gobies are sensitive to the use of several piscicides and the bottom-release formulations of some of these piscicides may have some application for the selective removal of round gobies (Schreier et al. 2008). However, the potential to eradicate *N. melanostomus* populations depends on the location and the opportunity for dispersal and establishment of populations. If broadly dispersed in large lakes or river systems, eradication is probably impossible (Verreycken 2019).
1.22. How likely are the biological characteristics of the organism to facilitate its establishment?	very unlikely unlikely moderately likely likely **very likely**	low medium high **very high**	Round goby is a generalist with a wide thermal tolerance; it uses a wide range of habitats and it is an opportunistic feeder (Kornis et al. 2012). The species has a high fecundity and is also a multiple batch spawner and nest guarder which are believed to be characteristics that enhance survival and increase of numbers of offspring which can indirectly favour establishment (Janáč et al. 2019). *Neogobius melanostomus* are also tolerant of very low dissolved oxygen levels (Charlebois et al. 1997).
1.23. How likely is the capacity to spread of the organism to facilitate its establishment?	very unlikely unlikely **mod. likely** likely very likely	low **medium** high very high	Because round goby is lacking a swim bladder, it is not a good swimmer. Still, upstream dispersal distances can be 4 km/year (Bronnenhuber et al. 2011), or even up to 14 km/year (Brownscombe & Fox 2012) making it possible to search for better sites for establishment. Downstream spread is faster (>16 km/year), and is most likely the result of goby early life stage drift (Janáč et al. 2013).

1.24. How likely is the adaptability of the organism to facilitate its establishment?	very unlikely unlikely moderately likely likely **very likely**	low medium high **very high**	Round goby is a generalist in habitat use (prefer rocky habitat but also thrives on sandy bottoms) (Erős et al. 2005) and it is an opportunistic feeder (broad range of prey items). These characteristics give round goby a high adaptability that favour establishment, as was noted in large parts of the invaded area.
1.25. How likely is it that the organism could establish despite low genetic diversity in the founder population?	very unlikely unlikely moderately likely **likely** very likely	low medium **high** very high	In North America, populations of round goby were founded by very large numbers of propagules and underwent no founder effects. Genetic evidence points to multiple invasion sources for this goby species, which appears related to especially rapid spread and widespread colonisation success in a variety of habitats (Stepien et al. 2005). In the Baltic Sea, a low genetic diversity of the first introduced round gobies was followed by rapid, site-specific genetic differentiation after only 10 generations. This evidence suggests that *N. melanostomus* rapidly adapt to new habitats, which may have contributed to its success in the Baltic Sea (Björklund & Almqvist 2010).
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.)	very unlikely unlikely moderately likely likely **very likely**	low medium high **very high**	Once round goby arrives in the RA area, establishment is almost certain as happened in many invaded areas in North America and Europe. Especially anthropogenic modified habitats, such as navigable rivers with rip-rap banks and shipping canals are at risk (Ray & Corkum 2001).
1.27. If the organism does not establish, then how likely is it that transient populations will continue to occur? 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.	very unlikely unlikely moderately likely **likely** very likely	low medium **high** very high	Round goby adapts well to different environmental circumstances so if the introduction of this fish species would occur and the organism would not be able to establish in certain sites, the specimens would at least survive and would continue to occur as long as new introductions happen.

1.28. Estimate the overall likelihood of establishment (mention any key issues in the comment box).	very unlikely unlikely moderately likely likely **very likely**	low medium **high** very high	- Establishment has happened in various geographic areas (North America, mainland Europe, Baltic Sea) making it very likely that establishment will happen in the RA area - Round goby is a generalist in habitat use, is an opportunistic feeder, and exhibits a reproductive strategy that favours establishment

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.)	minimal minor **moderate** major massive	low medium **high** very high	Round goby are typically sedentary (Björklund & Almqvist 2010) with limited home ranges (Ray & Corkum 2001), but individuals occasionally move long distances. A relatively high proportion of migrants in streams probably facilitates fast spread rates, with estimates ranging from 500 m/year on average (Bronnenhuber et al. 2011) to up to 1–4 km/year in select areas. High intraspecific competition between round gobies at high densities in streams suggests that density-dependent factors probably contribute to range expansion (Kornis et al. 2012). Brownscombe & Fox (2012) observed a rapid range expansion during the non-reproductive season at the upstream edge of range (up to 14.2 km/year). The downstream spread is even faster (>16 km/year) and is most likely the result of goby early life stage drift (Janáč et al. 2013).
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.)	minimal minor moderate **major** massive	low medium **high** very high	Shipping and boating are important vectors for human assisted spread. Inland ships and yachts can disperse the round goby eggs, larvae and adults across the RA area. When anglers use round goby as live bait they can transfer them over long distances (Kornis et al. 2012). Also interconnected river basins and regulated rivers enhance the spread of round goby (Mombaerts et al. 2014).
2.3. Within the risk assessment area, how difficult would it be to contain the organism?	very easy easy with some difficulty **difficult** very difficult	low medium high **very high**	Containment of freshwater fishes in large, open waters is extremely difficult. Round goby occurs preferably in large, regulated rivers, canals and lakes (Ray & Corkum 2001).

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.	All major navigable rivers, connected lakes and canals in the RA area.	low medium **high** very high	As introduction of round goby is likely to occur via ballast water or hull fouling, all major navigable rivers and canals with international ports are at immediate risk.
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** 10-33 33-67 67-90 90-100	low medium high **very high**	No round gobies recorded in the RA area yet.
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** 10-33 33-67 67-90 90-100	**low** medium high very high	Human-mediated spread and subsequent establishment can go fast as happened in previously occupied areas in North America and Europe e.g. within 5 years after the first record of round goby in the Flemish Region (Belgium) about 33–67 % of the suitable rivers and canals had established round goby populations (Verreycken, unpublished data).
2.7. What other timeframe (in years) would be appropriate to estimate any significant further spread of the organism in the risk assessment area? (Please comment on why this timeframe is chosen.)	10 **20** 40 80 160	**low** medium high very high	As the RA area has no freshwater connection to the already invaded areas, establishment and spread of round goby has to come from intentional and accidental human-mediated introductions. This obviously diminishes the propagule pressure and probably enlarges the timeframe for significant further spread.
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 **10-33** 33-67 67-90 90-100	**low** medium high very high	A timeframe of 20 years resulted in high proportions of endangered habitat/area to become invaded by round goby in other parts of the world. So this may be possible for the RA area too.
2.9. Estimate the overall potential for future spread for this organism in the risk assessment area (using the	very slowly slowly **moderately**	low **medium** high	- Although natural spread may be slow and limited upstream, downstream dispersal (i.e. drift of larvae) can be faster and further.

comment box to indicate any key issues).	rapidly very rapidly	very high	- Human-mediated activities (e.g. marine and inland shipping, bait-bucket transfer) are responsible for rapid, long-range dispersal of *N. melanostomus* (Hensler & Jude 2007; Roche et al. 2013). - The lack of a freshwater connection with other invaded areas and the fact that no round gobies are present in the RA area after a major invasion in NW Europe since 2000–2005 warrants a medium confidence score.

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?	minimal minor moderate **major** massive	**low** medium high very high	Aquatic invasion costs are underrepresented compared to terrestrial invasion costs and are mainly reported from the USA. The reported costs are principally a result of resource damages (74%); only 6% of recorded costs were from management (Cuthbert et al. 2021b). There are no exact data for round goby but the economic costs for damage by another small European fish species ruffe, *Gymnocephalus cernua*, in the USA over a 50-year time period was estimated to be US$53 billion (Cuthbert et al. 2021b) although most of this amount were potential costs. Haubrock et al. (2022) on the other hand report only US$28.93 of total costs (potential and observed) for ruffe in the USA and point out that there are many knowledge gaps in economic costs of invasive alien fish worldwide. They estimate that fish invasions have potentially caused the economic loss of at least US$37.08 billion (US2017 value) globally, from just 27 reported species.
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** minor moderate major massive	low medium high **very high**	The organism is not known to be present in the RA area.

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?	minimal minor moderate **major** massive	**low** medium high very high	There are no definitive studies on the economic costs of round goby anywhere in its invasive area. In the Great Lakes, largely because this species degrades indirect-use values, the costs are moderately difficult to measure. The most direct economic effect of *N. melanostomus* in the Great Lakes is associated with recreational angling. Depending on the target species, round goby either deters anglers from fishing due to frequent capture as by-catch, or encourages anglers to fish due to perceived increases in the frequency of above-average-sized fish (Kornis et al. 2012). Williams et al. (2010) estimated the cost of the invasive signal crayfish (*Pacifastacus leniusculus*) for the angling sector in the UK to be about £1,000,000 per year in control measures and lost angling revenue. Also round goby may possibly deter anglers from fishing due to frequent capture as by-catch and in this way cause losses in angling revenue. The costs for another small invasive fish species, topmouth gudgeon *Pseudorasbora parva*, in the UK may serve as a proxy for round goby. The economic impact of *P. parva* control in conjunction with their present and estimated future distribution, and their impact on the economic value of fisheries resources was estimated to be £2879.7 million (Britton et al. 2010), with management costs approximately £190,000 over 3 years.
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** minor moderate major massive	low medium **high** very high	The organism is not yet present in the RA area. General costs to manage invasive aquatic species (e.g. ballast water treatment measures, inspections, …) are not taken into account here.
2.14. How great are the economic costs **associated with managing** this organism likely to be **in the future** in the risk assessment area?	minimal minor **moderate** major massive	low medium **high** very high	There are no data on costs associated with management of round goby but Cuthbert et al. (2021a) report the total reported damage costs of invasive alien species for aquatic or semi-aquatic environments to be $29.8 million for Great Britain of which expenditure on managing invasions is a fraction (37%) of the costs incurred through damage. The Great Britain-wide cost of controlling freshwater invasive species was estimated to be approximately £26.5 million/year and even £43.5 million/year if management efforts were undertaken at all infested locations (Oreska & Aldridge 2011). N'guyen et al. (2018) conducted some removal experiments in the High Rhine in Austria and modelled the data to calculate the most efficient solution for eradication and/or control. Starting population control early after detecting the species requires in

			total fewer years (13 years for early start vs. 18 years for late start) to reach an eradication success rate of 95%. Removing adults only (vs. also eggs and larvae) proves to be the most efficient option (yearly effort of 1.76 h/m²) to eradicate the population. Monetary costs are not provided by N'guyen et al. (2018).
2.15. How important is environmental harm caused by the organism within its existing geographic range **excluding the risk assessment area**?	minimal minor moderate **major** massive	low medium **high** very high	Round goby is reported to exert competition to (van Kessel et al. 2016; Janáč et al. 2019) and predation on native biota, especially small benthic fish species (review in Kornis et al. 2012). Its predation, especially on zebra and quagga mussels, may have several indirect effects, potentially altering nutrient and contaminant pathways (Hogan et al. 2007; Ng et al. 2008). Round goby impacts on native benthic fish, percid, gadid and salmonid species are life stage and ecosystem dependent: round goby prey on eggs and fry, thus negatively affecting these fish species but adult percids, gadids and salmonids also prey on round gobies, but their importance as food item varies across ecosystems (Hirsch et al. 2016). Hirsch et al. (2016) conclude from their review on impacts of round goby that the impacts are profound, but variable across ecosystems, life stages, and time scales. Van Kessel et al. (2016) report a sharp decline (from 20 to 1 individual per 100 m² in 5 years time) of the protected, native *Cottus perifretum* in the River Meuse as a consequence of predation and competition for shelter and/or food with round goby. Similarly, Janáč et al. (2019) report a negative impact on native 0+ fish abundance and species richness in the Upper Elbe river. In the Border Meuse, which constitutes the border between Belgium and the Netherlands, native bullhead completely disappeared in less than 10 years after the arrival of (high densities of) round goby (Verreycken, unpublished data).
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** minor moderate major massive	low medium high **very high**	The organism is not known to be present in the RA area.
2.17. How important is the impact of the organism on biodiversity likely to	minimal minor	low medium	Round goby is known to exert high competitive pressure on other small benthic species. In North America (mottled sculpin, *Cottus bairdii*) as well as in Europe

be in the **future** in the risk assessment area?	moderate **major** massive	**high** very high	(*Cottus gobio*, *C. perifretum*) sculpin species were severely reduced in abundance (and even disappeared from some stretches of invaded rivers) (Dubs & Corkum 1996; van Kessel et al. 2016; Janáč et al. 2019; Verreycken unpublished data). This decline of *Cottus gobio* may also be expected in the RA area after round goby invasion, especially when round goby reaches high densities. The impacts of round goby, however, are variable across ecosystems, life stages, and time scales (Hirsch et al. 2016), thus uncertainty about the importance of the impact on biodiversity remains. This can be illiustrated by round goby research in the Czech Republic where Janáč et al. (2016) report no negative effect of round goby presence on native 0+ fish abundance 3-5 years after its invasion in the River Dyje; while Janáč et al. (2019) do report negative impacts on native 0+ fish abundance and species richness in the Upper Elbe river only four years after invasion.
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** minor moderate major massive	low medium high **very high**	The organism is not known to be present in the RA area.
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**?	minimal minor moderate **major** massive	low medium **high** very high	In the Great Lakes, round goby changed the nutrient cycle by extensively feeding on dreissenid mussels and thus accumulating contaminants. This way there is a transfer of contaminants to upper trophic levels and predatory fish, such as yellow perch *Perca flavescens*, walleye *Sander vitreus* and smallmouth bass *Micropterus dolomieu*, which are also used as food fish, accumulate high doses of contaminants (Azim et al. 2011) and may not be safe to eat. Round goby has altered food webs in the Great Lakes and the Baltic Sea (Kornis et al. 2012). Also in the RA area, dreissenid mussels, known to filter the water and accumulate contaminants, are present as food for a possible arrival of round goby. Many predatory fish species specialise on round goby as an easy food source (see Kornis et al. for overview), this way well-liked species for consumption (e.g. pikeperch, eel, …) may get in touch with high doses of

			contaminants which may be dangerous for anglers taking fishes from the wild to consume.
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** minor moderate major massive	low medium high **very high**	The organism is not known to be present in the RA area.
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?	minimal minor **moderate** major massive	low **medium** high very high	Several species targeted by conservation efforts may suffer reduced recruitment as a result of egg depredation by *N. melanostomus* or may decline by competition for food and habitat. Some counties/regions allocate a lower WFD classification to waters with non-native species e.g. England follows the UK-TAG (UK Technical Advisory Group on the Water Framework Directive) alien species classification recommendations for high status water bodies to downgrade to good status where high impact alien species are established (Boon et al. 2020).The UK-TAG's Alien Species Group ranks non-native aquatic species by their perceived risk and for species that have been risk assessed for the GB Non-Native Species Secretariat (NNSS), the risk ranks published by the NNSS are used.
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** minor moderate major massive	low medium high **very high**	No native *Neogobius* species exist in the RA area.
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 minor **moderate** major massive	low **medium** high very high	A transfer of contaminants to upper trophic levels (accumulation of high doses of contaminants in piscivorous food fish) by round goby may cause human health issues when the contaminated fish are eaten frequently (Kornis et al. 2012). In some cases, round goby predation on the eggs of sport fish has resulted in the halt of fisheries and the placement of catch restrictions in order to counteract reduced recruitment (Kornis et al. 2012). Round goby is also considered as a nuisance species for anglers, round goby quickly takes all bait presented on a hook on the bottom of a water and gets hooked instead of the targeted species. This may repeat plenty of times (e.g. 100 bites per hour)

			before the angler catches the targeted fish species (Kornis et al. 2012; Verreycken, pers. obs.)
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 **minor** moderate major massive	low **medium** high very high	Round goby appears to have been involved in an outbreak of avian botulism in the Great Lakes region but was not the only source (Hannett et al. 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)	**NA** minimal minor moderate major massive	low medium high 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?	minimal minor moderate **major** massive	low medium **high** very high	Major impacts (e.g. Burkett & Jude 2015) were reported from many already invaded areas where natural control by other organisms was present.
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).	All major rivers and canals with international ports are expected to experience impacts from the invasion of round goby	low **medium** high very high	Environmental impact is especially expected in ecologically valuable river upper reaches with endangered native species. Round goby competition can lead to major declines and even extirpation of native benthic fishes and other species. Social impacts are most likely to occur at important angling waters. Round goby may deter anglers from fishing due to very frequent capture as by-catch. Economic impacts are probably the greatest where economically important predatory food fish are caught due to accumulation of contaminants in these piscivorous fish and because of possible high management costs.
2.28. Estimate the overall impact of this organism in the risk assessment area (using the comment box to indicate any key issues).	minimal minor moderate **major** massive	low medium **high** very high	- Competition for food and habitat with native benthic fish species leads to decline and extirpation of native fishes - Disturbance of food web - Lower economic angling value of invaded systems

RISK SUMMARIES			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	very unlikely unlikely **moderately likely** likely very likely	low **medium** high very high	Hull fouling and ballast water exchange are probably the main introduction pathways for round goby, especially considering the extensive network of freight vessels going between Northern Europe and the RA area. However, until now, no round gobies were detected in the RA area.
Summarise Establishment	very unlikely unlikely moderately likely likely **very likely**	low medium **high** very high	Round goby has a high tolerance for a wide range of habitats, conditions, and prey items. It has become established and is widespread in North America (Great Lakes region) and Europe (everywhere except in the British Isles (Ireland, Great Britain) and in most of the Mediterranean area (Spain, Portugal, Greece).
Summarise Spread	very slowly slowly **moderately** rapidly very rapidly	low **medium** high very high	Though natural spread may be slow to moderate, human-aided spread has made sure that this species spread rapidly everywhere in its non-native range.
Summarise Impact	minimal minor moderate **major** massive	low medium **high** very high	Economic, social as well as environmental impacts have been reported in its invaded range. Especially extensive competition for food and habitat with native benthic species may lead to decimation or even extirpation of certain native species.
Conclusion of the risk assessment	low medium **high**	low **medium** high very high	Once round goby is introduced in the RA area, chances of establishment are very high, they can rapidly spread and become very abundant. Especially in the sites where they are very abundant, round goby can exert major impacts on several levels.

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?	**Climate warming**	low **medium** high very high	Round goby has a wide thermal tolerance, but prefers warmer water (Reid & Ricciardi 2022). This is possibly why, across the Great Lakes, the species is most widespread and at its greatest densities in the warmest lake (Erie) and has the smallest range and lowest densities in the coldest (Superior) (Kornis et al. 2012). Although Roche et al. (2020) describe diminished chances for survival of round goby due to short term climate changes, most authors agree that round goby will benefit from future climate warming (Reid & Ricciardi, 2022; Christensen et al. 2012).
3.2. What is the likely timeframe for such changes?	5, 10, **20**, 50, 100 years	**low** medium high very high	
3.3. What aspects of the risk assessment are most likely to change as a result of climate change?	**Spread**	low **medium** high very high	Round goby may become more widespread in the RA area.
ADDITIONAL QUESTIONS - RESEARCH			
4.1. If there is any research that would significantly strengthen confidence in the risk assessment please summarise this here.	- Invasion pathways - Species Distribution Model	low medium **high** very high	- Research on the most plausible pathways for the RA area and on its control and management practices can aid to increase the confidence of parts of the risk assessment. - Species Distribution Model (SDM) can detail out the places the most at risk.

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

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