RISK ASSESSMENT SUMMARY SHEET

Chinese mystery snail (*Cipangopaludina chinensis*)

- A conspicuously large freshwater snail (shell height up to 65 mm), easily distinguished from native species.
- Locally established in two main areas in GB, which may be the result of aquarium discards.
- Potential impacts are not well understood but it has the potential to outcompete or displace native species, including rare native snail species in the Pevensey levels.
- Non-native populations have been present in the USA since the end of the 19th century. More recently (in 2007) it established in the Netherlands and subsequently Belgium, Spain and Germany. It is considered a medium risk in Europe.

Becky, inaturalist

History in GB

C. chinensis was first detected in GB in a large ditch at Pevensey Levels, East Sussex in 2018. It was subsequently found in multiple lakes in and around Southampton in 2022. It is a large conspicuous snail making detection and reporting more likely; however, to date it is only known from these locations.

Native Distribution

Native to China, Taiwan, Korea, eastern Russia and Japan (dark brown areas). Native range (dark brown) map from Kingsbury et al (2021). Question marks indicate areas where native status is uncertain or suspect.

GB Distribution

Map source: APHA

Impacts

Environmental (moderate, medium confidence)

- Could reduce native snail populations through competitive exclusion, altering nutrient cycles and decreasing algal biomass; however, this has not been demonstrated in the field.
- Has the potential to cause damage to the protected Pevensey Levels SAC (and other similar wetland grazing systems elsewhere in GB), thereby possibly endangering a range of rare / protected species such as *Anisus vorticulus*.

Economic (minor, low confidence)

- Expected to be minimal as in the USA (where the snail has been present for 140 years / in at least 36 States).
- There are no known *C. chinensis* management / eradication operations for the European populations, so economic costs are unknown.

Social (minimal, very confidence)

- In its native range *C. chinensis* is a host for several platyhelminth parasites that affect man such as human intestinal fluke, but throughout the USA, there have been no reported cases of transmission.

Introduction pathway

Escape or deliberate release resulting from use in aquaria or for food consumption is the most likely introduction pathway.

Spread pathway

Natural (minor, high confidence) via water corridors or waterfowl.

Human (moderate, medium confidence) deliberate release or accidental as a contaminant, on boats or water channel maintenance machinery.

Summary

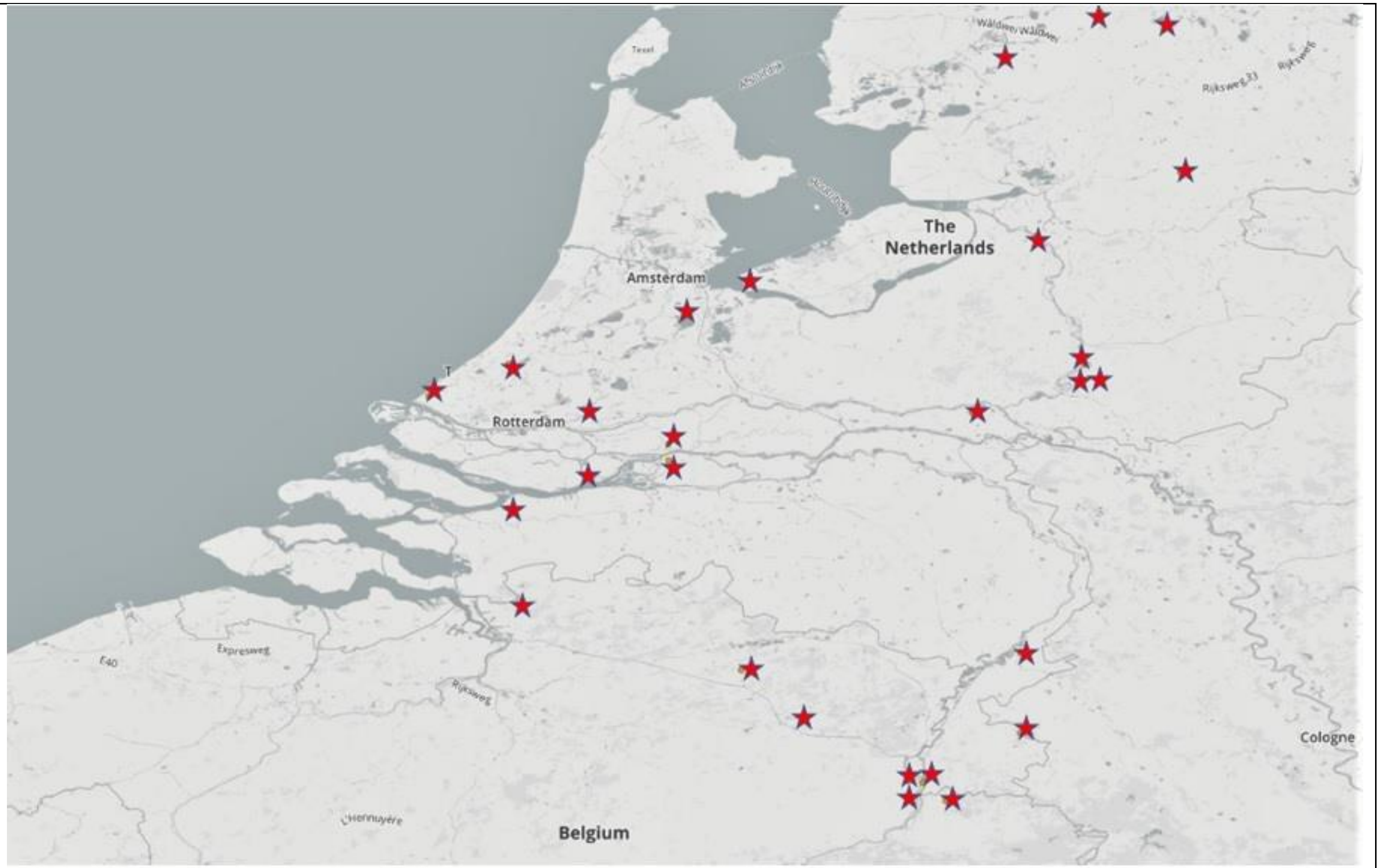
	Response	Confidence
Entry	VERY LIKELY	VERY HIGH
Establishment	VERY LIKELY	VERY HIGH
Spread	SLOW	MEDIUM
Impact	MODERATE	MEDIUM
Overall risk	MEDIUM	MEDIUM

GB NON-NATIVE ORGANISM RISK ASSESSMENT SCHEME
Name of organism: *Cipangopaludina chinensis*, Chinese Mystery Snail **Author:** Dr. Martin J. Willing, Conchological Society of Great Britain & Ireland **Risk Assessment Area:** Great Britain **Version:** Draft 1 (Sep 2022), Peer Review 1 (Dec 2022), NNRAF 1 (Dec 2022), Peer Review 2 (Feb 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 assessment will form part of the evidence used to inform the Committee's decision. This species was selected for consideration following its detection in England in 2018. A rapid risk assessment undertaken in 2020 identified this as a medium-risk species potentially introduced as a result of use in aquaria or for food. This assessment updated the rapid risk assessment.

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?	***Cipangopaludina chinensis*** (Gray, 1833). Common names include **Chinese Mystery Snail**, also Oriental Mystery Snail, Asian Apple snail. An alternative and quite widely used name is *Bellamya chinensis*. Thus Collas et al. (2017) argue that the snail be placed in the genus *Bellamya* on anatomical grounds following Smith (2000). Others though (e.g. Kipp et al 2020) use *Cipangopaludina chinensis*. The latter name is adopted in this document following MolluscaBase (2019). The snail can be readily distinguished from closely related operculate gastropods *Viviparus viviparus* and *V. contectus* found in the UK (Rowson et al. 2021). **Synonyms and Other Names:** *Bellamya chinensis, Paludina chinensis, Vivipara chinensis, Cipangopaludina leucostoma, Cipangopaludina diminuta*	
2. If not a single taxonomic entity, can it be redefined? (If necessary use the response box to re-define the organism and carry on.)	N/A	
3. Does a relevant earlier risk assessment exist? (Give details of any previous risk assessment.)	Yes There have been several risk assessments conducted for this species that are relevant, including a rapid risk assessment conducted for GB (Willing & Jones 2020). The results of these are briefly summarised below. Rapid risk assessment for GB (Willing & Jones 2020) • Entry = very likely, very high confidence • Establishment = very likely, very high confidence • Spread = rapid, low confidence (based primarily on human facilitated spread) • Impact = moderate, low confidence (based primarily on environmental impact) • Conclusion = medium risk, low confidence Risk assessment for the Netherlands using the Harmonia+ scheme (Matthews et al 2017b) • Introduction = high, high certainty • Establishment = high, high certainty	

	• Spread = medium, medium certainty • Impact score = medium, medium certainty (based primarily on environmental impact) • Overall risk score = medium <u>Risk assessment for the EU</u> using modified version of the GB NNRA scheme (Lucy and Davies 2022) • Introduction = very likely, high confidence • Establishment = very likely, high confidence • Spread = moderately, low confidence • Impact = moderate, low confidence • Overall risk = moderate, low confidence Other assessments of risk include: • New York Fish and Aquatic Invertebrate Invasiveness Ranking Form (Adams and Schwartzberg, 2013) – resulted in a 'very high' risk rating (scored of 83 out of 100) based on four risk categories: ecological impact, biological characteristics and dispersal ability, ecological amplitude and distribution and difficulty of control. • GB horizon scanning (Roy et al, 2019) - identified this species to be one of the top 30 non-native species likely to become invasive in the next 10 years. • EU horizon scanning (Roy et al, 2015) - identified this species to be high risk and included it within the top 95 invasive species threats to the EU. A key aspect of earlier risk assessments for this species is potential impact. Risk assessments conducted for the Netherlands, EU and the rapid assessment for GB concluded that impact was moderate / medium with considerable uncertainty (low confidence for both GB and EU, medium certainty for NL). The Dutch assessment provides perhaps the most thorough review of the evidence on impact. In general, medium impact scores appear to be based on lab studies that demonstrate environmental impact may occur, but lower confidence relates to the lack of field evidence to support this. The EU risk assessment notes that current population levels of this species in Europe have not yet caused significant biodiversity impacts, but that this is understudied and there is potential to cause negative impacts in future.
4. If there is an earlier risk assessment is it still entirely valid, or only partly valid?	Partially

	All previous risk assessments provide useful information to help support this assessment, but none are entirely valid for GB. The rapid risk assessment is the closest to being valid; however, a more detailed assessment is required to support the GB Committee's consideration of this species for listing as a species of special concern.
5. Where is the organism native?	*C. chinensis* is native to China, Taiwan, Korea, eastern Russia and Japan (Global Invasive Database 2011).
6. What is the global distribution of the organism (excluding the risk assessment area)?	Beyond the snail's native range, it has been introduced to several regions of the world. Thus, it was introduced into the USA at the end of the 19th century for the Asian food market (Jokinen 1982, Karatayev *et al.* 2009). Since then, the species has spread widely throughout the country. Kipp *et al.* (2020) show the widespread presence of the snail across the USA with populations present in 36 States (including three of the Hawaiian Islands). The snail is especially widespread towards the northeast of the States with 41, 37, 25 and 17 reported sites in Wisconsin, Minnesota, Michigan and Ohio respectively. In Europe the species was first recorded in the Netherlands in a River Meuse floodplain lake at Eijsder Beemden in the south of the country in 2007 (Piters 2007). By 2016 the snail had established 12 populations in the country in the Rhine and Meuse basins (Collas *et al.* 2017). It was also first recorded in Belgium in 2017 (Van den Neucker *et al*. 2017). In the Netherlands the presence of *C. chinensis* at scattered, isolated sites is considered probably due to multiple and independent introductions, probably from aquarium and pond disposals or escapes from pond and garden centres (Collas *et al.* 2017, Matthews *et al.* 2017a). By 2022 the snail has spread to a further three closely situated sites in Belgium whilst in the Netherlands it has now been reported from a total of 23 sites scattered throughout the country, a nearly 100% increase since 2017 (GBIF 2022). Recent finds also confirm the arrival of the snail in two additional European countries. Thus, in October 2020, live *C. chinensis* specimens were confirmed from near the mouth of the Algar River, in the Alicante province of Spain (Núñez de Arenas *et al*. 2020) and the snail was also reported from the Hengsteysee stretch of the River Ruhr near Hagen, Germany on 25/4/2021 (https:///observations/75219011).

	 ***Cipangopaludina chinensis* distribution in North-west Europe in 2022 (23 sites in the Netherlands & 4 sites in Belgium)** Map constructed on an extract from: GBIF (2022) https://www.gbif.org/occurrence/map?continent=EUROPE&country=BE&country=NL&taxon_key=9738098 [Accessed 28/11/2022] Fig.1 *Cipangopaludina chinensis* presence in NW Europe.
7. What is the distribution of the organism in the risk assessment area?	*C. chinensis* is now known from two main (widely separated) locations in the GB risk assessment area: 1. Pevensey Levels, East Sussex and 2. Southampton area, Hampshire.

	(1) Pevensey Levels: The snail was first recorded in September 2018 in a ditch on Glynleigh Level at NGR: TQ61143 07123 (Fig 2), a location lying on the south-west margins of the Pevensey Levels (Willing 2019a, Rowson 2019). The site was revisited on 27/7/2019 and a survey undertaken of the ditch where the snail was originally discovered together with several adjoining ditches (Fig 3). This survey found the snail in the original ditch spread along about 420m. Further surveys were undertaken in February/March 2021 (Willing 2021a), August 2021 (Willing 2021b) and April 2022 (Willing 2022a). These demonstrated that *C. chinensis* had extended its range slightly in the infested ditch (extending the infested presence to about 450m) but that it was not found outside of the single infested ditch. eDNA monitoring undertaken by Natural England from 2021 to 2023 (Rees et al. 2022a, b; Rees et al 2023a) confirmed that the *C. chinensis* has not spread to the main Glynleigh Sewer and is confined to the single infested ditch. However, recent survey work in October 2023 has shown that *C. chinensis* has now spread to one side ditch (Rees et al 2023b). This was confirmed by adult shells found behind the recently installed coffer dam and some >120m beyond the coffer dam (Fig 3). Study of a cohort of adult shells collected in 2018/2019 suggested that the site had been colonised no later than the period 2013 – 15 meaning that in 2022 the site has been occupied for between 7 – 9 years.

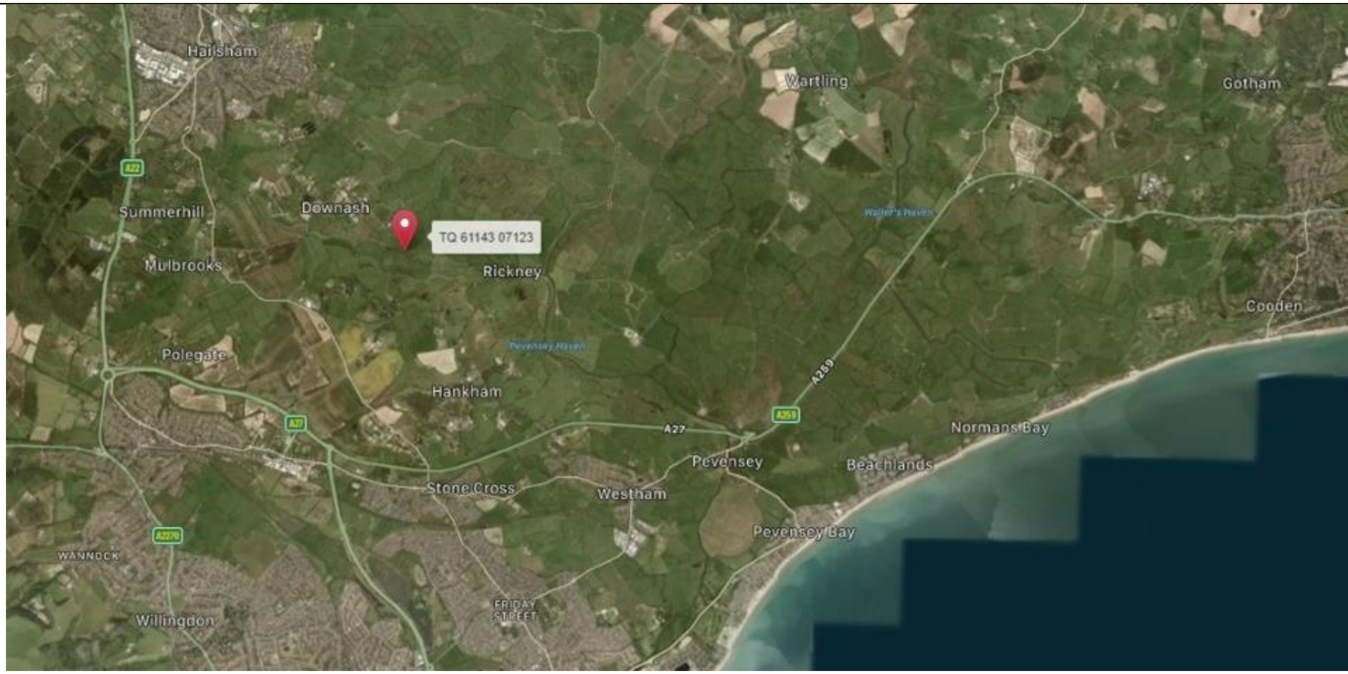


Fig 2. Regional map to show the location of the Pevensey Levels sites.

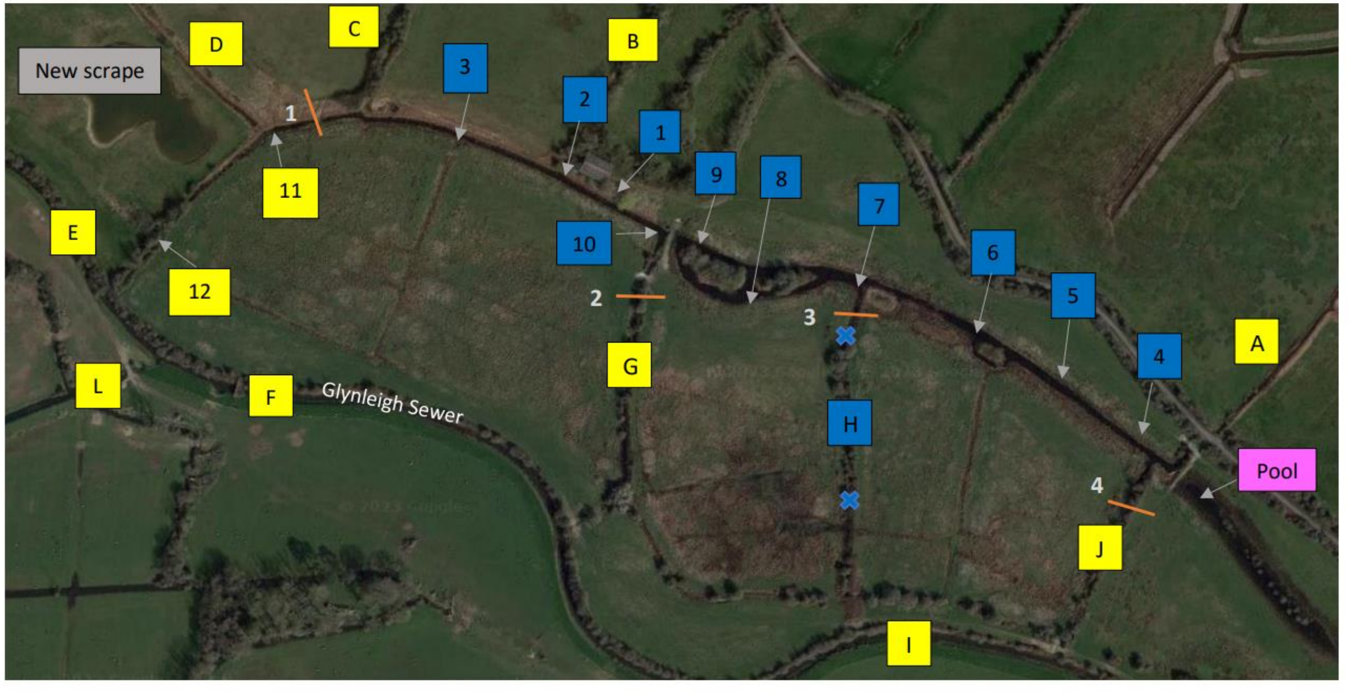


Fig 3. Map of the Pevensey Levels summarising the situation in October 2023 (including the addition of four coffer dams). Blue labels show where *C. chinensis* was found and yellow where *C. chinensis* was not found. Pink labels show sites with *Anisus vorticulus*. Numbers and letters indicate sampling sites and side ditches sampled by M. Willing and Natural England between 2019-2023. Orange lines indicate the sites of the four coffer dams installed in 2022/2023 (numbered 1 to 4 from left to right).

(2a) Southampton Common: On 15th June 2022 an iNaturalist report submitted on 26/1/2022: (https://www.inaturalist.org/observations/105706182) was picked up by the Conchological Society's Non-marine Recorder of large dead freshwater snail shells from a drained boating lake on Southampton Common (Fig 4). Study of images from the find confirmed these to be of *C. chinensis* (B. Rowson; personal communication). The finds were reported to Natural England and the GBNNSS on 18/6/2022. Survey visits to the sites by Natural England (24 – 25/8/2022) confirmed the presence of numerous dead shells and a single live specimen on the concrete margins in the original boating pond and additionally found plentiful live snails in another pond, the 'Ornamental Lake', lying about 100m to the north-west of the original site (Natural England, 2022) (Fig 5). A further survey was carried out in February 2023 to determine the overwintering survival in the drained Boating Lake. This confirmed the presence of live snail specimens surviving in the mud layer of the lake, indicating they can survive a prolonged period of lake drawdown (NE per coms).

The presence of numerous dead adult shells at the Boating Lake since January 2022 suggests that Chinese Mystery Snail (CMS) infestation may have occurred at least 5 years before. The adult snail shell cohort is likely to have included those from female snails which typically live for about 5 years (Jokinen 1982, Jokinen 1992). This would mean that infestation of the site would have occurred no later than 2017 with a site occupation of at least 5 years.

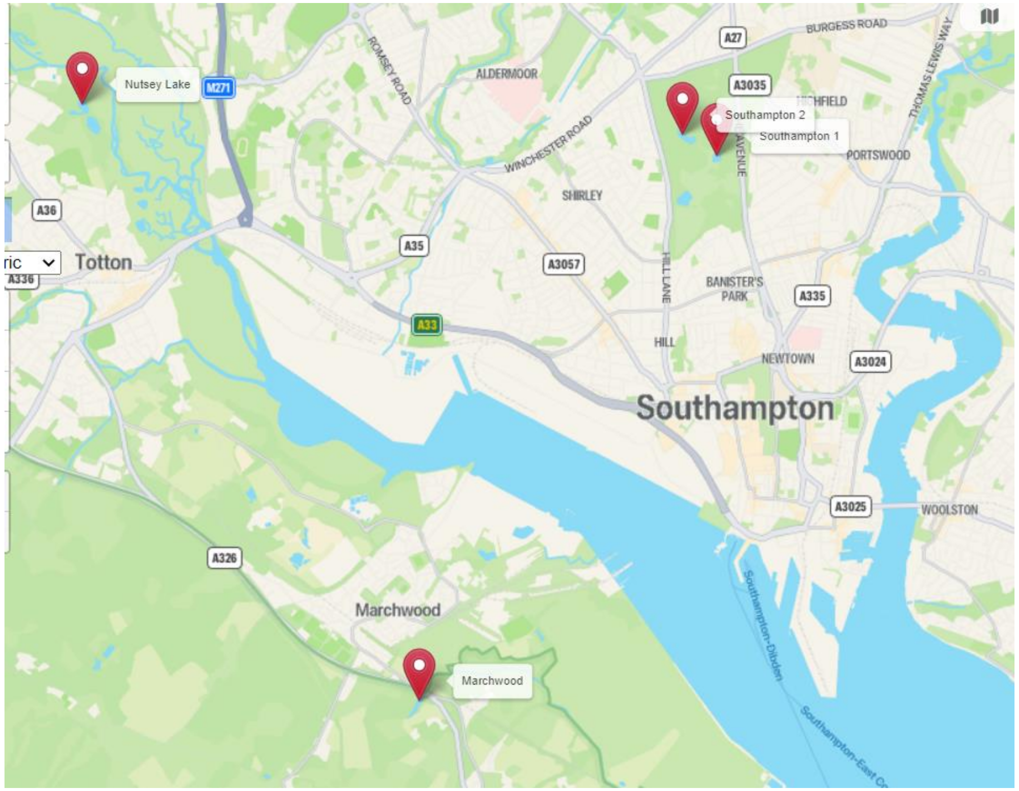


Fig 4. Regional map to show the general location of the Southampton sites.

Fig 5. The lake locations on Southampton Common.

<u>(2b) Marchwood and Lower Test Valley, Southampton</u>: In early July 2023, the Environment Agency reported finding large numbers of suspected *C. Chinensis* snails (live and shells) at two fishing lakes owned and managed by the Test Valley Angling Society in the Southampton area. One site is adjacent to the Testwood Lakes Nature

	Reserve and Lower Test Valley SSSI; the second site (Marchwood) is within the New Forest National Park boundary. The finds were reported to Conchological Society's Non-marine Recorder, Natural England and the GBNNSS on 6/7/2023. A biosecurity audit of the two sites was carried out by the GBNNSS in November 2023 and the angling club plan to put biosecurity and warning notices (relating to the presence of this invasive species) around the two infected lakes.
8. Is the organism known to be invasive (i.e. to threaten organisms, habitats or ecosystems) anywhere in the world?	Yes. Risk assessments from New York, the Netherlands and the EU have identified medium / moderate impacts associated with this species linked to its potential ability to displace native species through competitive exclusion, altering nutrient cycles and decreasing algal biomass as well as altering ecosystems through high rates of filtration. Although there are no data proving that the species is currently invasive and has much impact in Europe, the species has the potential to become problematic due to the high probability of human introduction, optimal habitat and climate matches, and high probability of impacts to infrastructure. Evidence of negative ecological effects is limited to mesocosm experiments from North America which suggests that *B. chinensis* may outcompete native snail species, increase water clarity and reduce algal biomass due to a high filtration rate, and increase the N:P balance and benthic-pelagic coupling. A lack of recorded ecological impacts of *B. chinensis* on North American aquatic ecosystems, including the Great Lakes, may be related to the generally low species densities observed there. (Matthews *et al* 2017b). For further discussion see 2.18 & 2.19 below.
9. Describe any known socio-economic benefits of the organism in the risk assessment area.	*C. chinensis* is of potential economic benefit as a food item and as a captive aquaria 'pet'. There is no evidence of *C. chinensis* being sold for human consumption in Britain; despite appeals for information in various UK publications (e.g. the author has received no reports of the sale of live *C. chinensis* in either oriental grocers (as a food item) or from garden and aquaria stockists (Willing 2019a, 2019b, 2022b)). Internet searches did, however, reveal a number of aquarium stockists apparently selling the snail (e.g. https://www.ebay.co.uk/itm/trapdoorsnails/254585970798?hash=item3b4681a06e:m:mZIWt7SqHZ6M347_LOznIUA&var=5543 16695503 – note this URL has subsequently been taken down).

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	There are approximately 5 active pathways relevant to the potential further entry into the GB risk area.
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).	A. Escape or deliberate release from commercial & private imports for aquarium trade as well as imports for food consumption. B. Stowaway with Angling equipment (& ecological field survey equipment). C. Dispersal with waterfowl and aquatic mammals. D. Contaminant on plants. E. Transport stowaway: Ships (ballast water, boat hulls and anchors).		

Pathway name:	A. Escape or deliberate release from commercial & private imports for aquarium trade as well as imports for food consumption.		
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	high	Escape from confinement (for food but chiefly for aquaria use) by accidental or deliberate release is considered to be the primary pathway in the USA and for the establishment of sites in Europe (for details of the Pevensey introduction see Spread 2.2 (2) below). It is possible, as suggested in the rapid risk assessment for this species (Willing & Jones 2020), that the CMS was intentionally introduced into the Pevensey Levels infested ditch for later harvesting to either supply the aquaria trade and /or for the Asian food market.
A1.4. 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	high	It is considered that the main *C. chinensis* introductory pathways are by the aquaria and oriental food markets (Karatayev *et al.* 2009, Strecker *et al.* 2011). Although *C. chinensis* has been shown to be marketed as a food item in the USA there is no evidence of it being sold as an ingredient for human consumption in the EU (Matthews *et al.* 2017a). It is claimed to have been released from aquaria into the Niagara River between 1931 and 1942 (Mills *et al*. 1993). In the Netherlands the presence of *C. chinensis* at scattered, isolated sites is considered probably due to multiple and independent introductions, probably from aquarium and pond disposals or escapes from pond and garden centres (Collas *et al.* 2017, Matthews et al 2017a, GBIF 2022). There is no information on the extent of imports that led to the invasion of this species in North America or continental Europe. However, the large number of apparently independent introductions in Europe (c. 12 in Belgium and 23 in the Netherlands – see response to question A6) suggests that there must be substantial numbers of this species in the aquarium / pond trade – which is considered the most likely pathway of introduction by Collas et al (2017). It is not clear the extent to which this species is in trade in GB, and this is complicated because snails available for sale are often not identified to species level and / or could be misidentified.

A1.9. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	likely	high	*C. chinensis* accidentally or deliberately released into a freshwater aquatic habitat may find that habitat suitable for it to survive and then reproduce.
A1.10. Estimate the overall likelihood of entry into the risk assessment area based on this pathway?	likely	high	This is judged to be the primary source of entry for many sites in the USA and the chief pathway of European introduction and then spread.

Pathway name:	B. Stowaway with angling equipment (& ecological field survey equipment).		
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)? (If intentional, only answer questions 1.4, 1.9, 1.10, 1.11)	accidental	medium	Contaminated bait buckets, keep nets and other fishing gear together with the soles of angling footwear could all act as potential unintentional transfer routes (especially for the smaller and so more easily overlooked juvenile stages of the snail).
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.	unlikely	medium	If considering transfer on angling equipment from Europe anglers would have to be fishing in one of the few infected sites and then any accidentally attached *C. chinensis* would need to survive the transfer unnoticed and then accidentally get introduced into a potentially suitable habitat in the risk assessment area; considered to be an unlikely chain of circumstances.

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 whether the organism could multiply along the pathway.	unlikely	high	Unlikely; any inadvertently transferred snails would likely be small juveniles that have a lower ability to survive desiccation than full grown adults (Havel 2011). Reproduction along the pathway is very unlikely.
B1.6. How likely is the organism to survive existing management practices during passage along the pathway?	unlikely	medium	Unlikely; see 1.4 & 1.5 above.
B1.7. How likely is the organism to enter the risk assessment area undetected?	likely	medium	Being a large and readily detected snail it is unlikely to enter the risk assessment area undetected as an adult although a juvenile snail might avoid detection due to its small size.
B1.8. How likely is the organism to arrive during the months of the year most appropriate for establishment?	likely	medium	*C. chinensis* may breed during the warmer months of the years but live for several years and so it would not seem to matter when a snail was introduced to a potentially suitable habitat; it could survive there until such times as reproduction was possible.
B1.9. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	unlikely	medium	It is unlikely that large readily seen adult snails would get transferred undetected, but the smaller juveniles might avoid detection (e.g., if trapped in a keep net) but that could then transfer into a new habitat in the risk assessment area, again an unlikely chain of events.
B1.10. Estimate the overall likelihood of entry into the risk assessment area based on this pathway?	unlikely	high	Although theoretically possible this route seems an unlikely pathway based upon the improbable chain of events that would be required for *C. chinensis* to get accidentally trapped in or on angling equipment and then transported, unnoticed and then accidentally released again in another part of the risk assessment area (if being transferred from within it e.g. from Southampton) or from continental Europe.

Pathway name:	C. Dispersal with waterfowl and aquatic mammals.		
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)	natural	low	In addition to human assisted spread there are also suggestions that waterfowl and some aquatic mammals may also act as dispersal agents (Claudi & Leach 2000) and Soes *et al.* (2016) report that *C. chinensis* has been observed as a food source for waterfowl and rodents. There has been some discussion concerning the possible spread of Asian Clams *Corbicula fluminea* by several water birds (e.g., Aldridge & Müller 2001) and perhaps similar arguments might equally apply to *C. chinensis. C. fluminea* are thick shelled bivalves that can tightly shut their valves to survive periods of time out of water or short-term water pollution incidents. As a member of the Viviparidae the snail can also very effectively 'close-shop' by way of its tight-fitting operculum (it is able to survive 8 weeks of drought) (Havel 2011, Unstad *et al*. 2013). Thompson & Sparks (1977) demonstrated that while *C. fluminea* could not survive passage through the digestive tract of Lesser Scaup Ducks *Aythya affinis* the clam would survive regurgitation from the gizzard enabling them to be potentially transported short distances over land and sea. Similarly, Oka *et al.* (1999) found that in Japanese lakes the clam could survive within the gizzards of clam-feeding tufted ducks *Aythya fuligula* and so allowing release elsewhere following regurgitation. If *C. chinensis* (perhaps especially smaller immature specimens) are similarly consumed by mollusc-eating diving ducks and other waterfowl then it is possible that they might also be able to be spread by gizzard regurgitation. The potential distance of spread would depend upon the snail's survival time in a particular bird's gizzard; unfortunately, it has not been possible to locate research data providing this information.
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?	very unlikely	high	The nearest known continental sources of *C. chinensis* are present in Belgium and the Netherlands (see 'Organism Information' 6 above). For further entry into the GB risk assessment area a mollusc eating duck or other waterfowl (e.g. tufted ducks *Aythya fuligula)* would need to have fed at one of the few continental sites and then undertake a flight (possibly taking several hours) over the North Sea to then regurgitate their gizzard contents in a suitable freshwater habitat in eastern

Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place.			England whilst the snails were still alive. This chain of events seems extremely unlikely to occur, but it is theoretically possible.
C1.5. 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.	moderately likely	low	With no known data on *C. chinensis* survivability in duck gizzards this is not possible to resolve. The snail would not multiply along the pathway.
C1.6. How likely is the organism to survive existing management practices during passage along the pathway?	N/A	N/A	N/A
C1.7. How likely is the organism to enter the risk assessment area undetected?	very likely	very high	In the unlikely circumstance of a snail arriving in the risk assessment area then its regurgitation from a duck (or waterfowl) gizzard would almost certainly not be observed.
C1.8. How likely is the organism to arrive during the months of the year most appropriate for establishment?	likely	high	*C. chinensis* may breed during the warmer months of the years but live for several years and so it would not seem to matter when a snail was introduced to a potentially suitable habitat.
C1.9. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	unlikely	medium	Diving ducks and other mollusc consuming waterfowl if arriving in GB from Continental Europe might well chose a freshwater habitat that might support the snail, but establishment would depend upon gizzard regurgitation into an aquatic habitat rather than on land (e.g., lake / pond margin) where any transferred snails might die.
C1.10. Estimate the overall likelihood of entry into the risk	Very unlikely	high	This is an unlikely pathway; the probability that each stage in the complex pathway being successful for snail transfer is most unlikely.

assessment area based on this pathway?			

Pathway name:	D. Contaminant on plants.		
D1.3. 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)	accidental	high	There is a theoretical chance that *C. chinensis* could be introduced to the GB risk assessment area attached to imported water plants from either North America or more likely from aquarium stockists in NW Europe. A few literature sources suggest the possibility of accidental transfer of the snail in traded water plants (for aquaria and / or outdoor ponds); it has been suggested that one of the introductory pathways of *C. chinensis* into the USA was as a passive attachment to ornamental lotus plants (Smith, 1995 in Martin 1999).
D1.4. 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	Accidental transfer would require the presence of the snail at the horticultural centre. Whereas small non-native species (e.g. *Gyraulus chinensis*, *Planorbella* spp) are occasionally found associated with aquaria plants they are relatively small and so more easily overlooked than a large snail (sizeable even as juveniles which typically have a 'birth' height of 6 – 7mm and shell width of 7 – 8mm: personal measurements of newly emerged Pevensey snails) such as *C. chinensis.* Accidental contamination of this pathway seems highly unlikely.
D1.5. 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.	moderately likely	medium	If *C. chinensis* happened to be carried in imported water plants, then it might be able to breed; the snail can reproduce both sexually and probably parthenogenetically. Although the snails are single-sexed, females have the potential (as do other members of the Viviparidae) to reproduce by parthenogenesis, meaning that a single female introduced into a habitat might establish a new population (a single female can produce up to 65 young per year (Johnson 1999, Mackenzie 2000)). (See also Probability of establishment 1.22 below).

D1.6. How likely is the organism to survive existing management practices during passage along the pathway?	unlikely	medium	*C. chinensis* is likely to survive transport in imported aquatic plants (either kept damp or in water). It is unlikely that adult snails would get transported as they would be readily visible but juvenile *C. chinensis* are more likely to avoid detection.
D1.7. How likely is the organism to enter the risk assessment area undetected?	likely	high	Being a large and readily detected snail it is unlikely to enter the risk assessment area undetected as an adult; a juvenile snail might avoid detection.
D1.8. How likely is the organism to arrive during the months of the year most appropriate for establishment?	likely	high	*C. chinensis* may breed during the warmer months of the years but live for several years and so it would not seem to matter when a snail was introduced to a potentially suitable habitat; it could survive there until such times as reproduction was possible.
D1.9. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	Very unlikely	high	Contaminated imported water plants would, in the first instance be retained at a dealer and then sold for introduction to an artificial habitat (pond, tanks in hot house etc); any accidentally transferred snail would then need further transfer to a 'wild' habitat from there. Deliberate disposal of pond or aquaria contents into a 'wild' freshwater habitat could lead to accidental release of the snail.
D1.10. Estimate the overall likelihood of entry into the risk assessment area based on this pathway?	Very unlikely	high	Such transport seems highly unlikely as the imported plants would need to have come from a source also infested with a breeding population of a large and readily recognised snail.

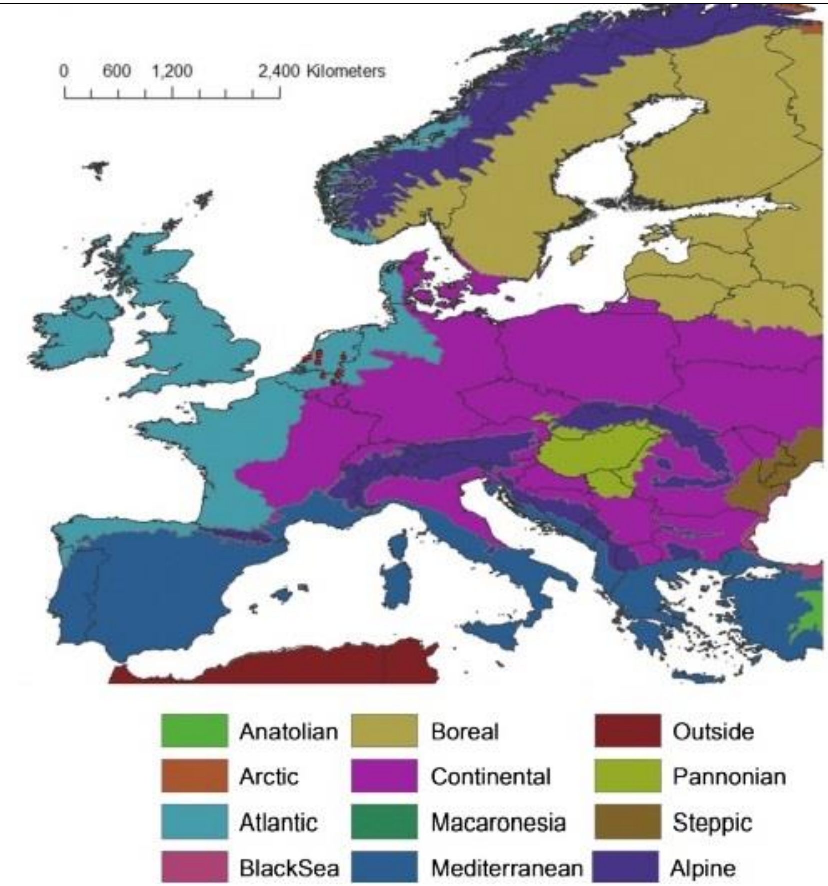
Pathway name:	E. Transport stowaway: Ships (ballast water, boat hulls and anchors).		
E1.3. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)?	accidental	high	*C. chinensis* might be transported from infested water bodies to new sites either attached to boats or in ballast water. The ability of the snail to attach to boat hulls in the USA and to survive long periods out of water means that accidental transport on recreational boats (both overland on trailers and via waterway networks) is feasible (McAlpine et al. 2016, Havel 2011, Havel et al. 2014). Boat related movement as one possible pathway is supported by a survey of 21

(If intentional, only answer questions 1.4, 1.9, 1.10, 1.11)			American lakes where the snail was more likely to be found at sites near boat launches with a decrease in presence with increased distance from such sites (Solomon et al. 2010). *C. chinensis* could readily be removed from a site on anchor chains contaminated with bottom sediments. *C. chinensis* transport in ballast water is considered unlikely as the snail does not have a free-swimming planktonic stage.
E1.4. 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	Contaminated boats would need to have been in some of the currently few infected waters in continental Europe and then transferred (rather than sail from the continent in sea water … it is important to remember that *C. chinensis* is a species restricted to freshwater habitats) to the GB risk assessment area whilst the snails were still alive and then reach a potentially suitable habit where the snails might get unintentionally released; an improbable set of circumstances. In the unlikely chance of this happening, it is doubtful that more than one or two might get transferred and these would most likely be small and vulnerable juveniles.
E1.5. 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	high	It is difficult to estimate the chances of snail survival without knowing how they were being transferred by this pathway. Reproduction would not seem possible on this pathway.
E1.6. How likely is the organism to survive existing management practices during passage along the pathway?	unlikely	high	If boat hulls were washed and anchor chains cleaned, then survival seems unlikely; conversely a lack of such procedures would make survival more likely.
E1.7. How likely is the organism to enter the risk assessment area undetected?	likely	medium	Being a large and readily detected snail it is unlikely, in certain circumstances (such as attached to or to a sail board), to enter the risk assessment area undetected as an adult; a juvenile snail might avoid detection.

E1.8. How likely is the organism to arrive during the months of the year most appropriate for establishment?	likely	high	*C. chinensis* may breed during the warmer months of the years but live for several years and so it would not seem to matter when a snail was introduced to a potentially suitable habitat; it could survive there until such times as reproduction was possible.
E1.9. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	very unlikely	high	Unlikely; see 1.4 above.
E1.10. Estimate the overall likelihood of entry into the risk assessment area based on this pathway?	unlikely	high	

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 likely	very high	Entry into the risk assessment area has taken place (two areas colonised). In the case of the Pevensey Levels site, it is possible that the snail was deliberately introduced for later harvesting, as was suggested in the rapid risk assessment (Willing & Jones 2020). The mode of entry to the sites in/around Southampton are unknown.

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	very high	*C. chinensis* can live in a remarkably wide range of climatic conditions. The known invasive geographic distribution of *C. chinensis* (the United States, North-West Europe) includes a very wide range of ecoclimatic zones including all of those present in Great Britain (Kipp *et al*. 2020, Collas *et al*. 2017, Matthews *et al*. 2017a, Van den Neucker *et al*. 2017). In the USA the snail is present in all ecoclimatic zones present in the country ranging from tropical (Hawaii), subtropical (Florida) to cool temperate conditions (e.g., New York State, Wisconsin, Minnesota, Michigan and Ohio). Conditions in Belgium and the Netherlands closely match those of much of eastern England. The UK is within the Atlantic Biogeographical Region (Fig.6) together with a considerable portion of north-western Europe including all areas in the Netherlands and Belgium currently supporting recruiting *C. chinensis* populations (Matthews *et al*. 2017a, 2017b). The snail has also recently been recorded in Spain and Germany, Mediterranean and Continental biogeographic regions respectively (see A.6 above). As previously stated, the snail has already established breeding populations at four sites within the risk assessment area with colonisation estimated to be at the latest 2013 - 2015 for Pevensey Levels and 2017 for Southampton. These sites may, of course have been colonised well before these dates.

			 Fig. 6. Biogeographic regions in Europe displaying the presence of *C. chinensis* in NW Europe in the Atlantic biogeographic regions which includes the whole of the UK 'risk assessment area'. (Extract from Matthews *et al* 2017b).
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	very likely	very high	*C. chinensis* has a remarkably wide tolerance of a variety of water conditions. It is a species that typically lives in still or slowly flowing water bodies (ponds, lakes streams and rivers) and in such situations it is found on a variety of substrates including silt, sand and mud (Jokinen 1982, Stancykowska *et al*. 1971). In eastern North America the species lives in a wide range of water

assessment area and the organism's current distribution?			conditions ranging from hard to soft. It has been found in waters with pH 6.5–8.4, calcium concentration of 5–97 ppm, magnesium concentration of 13–31 ppm, oxygen concentration of 7–11 ppm, depths of 0.2–3 m, conductivity of 63–400 µmhos/cm, and sodium concentration of 2–49 ppm (Jokinen 1982, Jokinen 1992, Stanczykowska *et al.* 1971). It can tolerate conditions in stagnant waters near septic tanks (Perron & Probert 1973) and is a 'temperature-hardy' species capable of surviving at temperatures as high as 45oC and for prolonged periods < 0 C (Burnett *et al.* 2018). This wide tolerance means a wide range of aquatic habitats across much of lowland Britain could be colonised by the snail. It is more likely to have a far more restricted potential presence in the upland regions of western England, much of Wales, central northern England, and upland areas of Scotland. Many upland waters are likely to be less suitable for the snail as they typically (1) have a lower pH (more acidic) and (2) are base-poor with lower levels of dissolved Ca2+ ions. Both factors would affect the ability of *C. chinensis* to form its thick shell. Additionally, many still or slow flowing upland water bodies (tarns, lochs, llyns & lakes) are often oligotrophic; *C. chinensis* typically thrives in eutrophic conditions rich in organic sediments and suspended organic matter. In addition to often unsuitable water quality, upland streams and rivers are too fast flowing to support *C. chinensis* (it being largely confined to still or slowly flowing water).
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	*C. chinensis* should be able to thrive in the protected and sheltered conditions present in artificially maintained habitats such as glasshouses, aquaculture facilities, terraria and zoological gardens. It is of course widely suggested that many of the introduction events in both the USA and Europe came from deliberate or accidental aquaria releases.

1.15. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in the risk assessment area?	widespread	very high	It was suggested in 1.13 above that potentially suitable *C. chinensis* habitat is widespread across lowland areas of GB especially in slow-flowing and still waters (a very wide range of habitats including ditches, permanent pools and ponds, lakes, canals, slow-flowing rivers and lakes).
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?	N/A	very high	It does not require another species.
1.17. How likely is it that establishment will occur despite competition from existing species in the risk assessment area?	very likely	very high	No documented evidence has been located (for the USA and Europe) to suggest that the establishment of invasive *C. chinensis* populations have been impeded by competition from native species. These include obligate and facultative filter feeders such as unionid mussels, invasive *Dreissena polymorpha* and *D. bugensis* as well as closely related operculate gastropods *Viviparus viviparus* and *V. contectus*.
1.18. How likely is it that establishment will occur despite predators, parasites or pathogens already present in the risk assessment area?	very likely	high	The establishment of *C. chinensis* outside of its native range in the USA and Europe (and so in the GB risk assessment area) may have been assisted by the absence of parasites and pathogens found in its native Asian range. Collas *et al.* (2017) supports such a view where they state, "*Snail species have a competitive advantage at a low trematode infection rate, as trematode infection lowers reproduction and survival*". In its native Asian range the snail is often infested by trematode species but in the States trematode infection of the snail is rare (Bury *et al.* 2007; Harried *et al* 2015). Ironically *C. chinensis* infestation of habitats already infested with invasive Signal Crayfish *Pacifastacus leniusculus* may be impeded as this species is implicated with a denudation of native gastropod species in parts of the upper Thames catchment (Rowson *et al.* 2021).

1.19. How likely is the organism to establish despite existing management practices in the risk assessment area?	very likely	high	The wide range of freshwater habitats potentially suitable for *C. chinensis* colonisation are managed in a very wide variety of ways (e.g. the regular rotational regimes of ditch clearance, the irregular clearance of ponds and small lakes, the dredging of some rivers). This makes any analysis of management techniques problematic and so perhaps of only slight relevance here.
1.20. How likely are management practices in the risk assessment area to facilitate establishment?	likely	high	The potential for the accidental spread and subsequent establishment is discussed below in 'Spread' 2.2 point 5.
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 likely	high	*C. chinensis* can tightly shut their shells with an operculum assisting them to withstand prolonged periods of drought (see 1.22 below) reducing the effectiveness of drawdown eradication strategies. Although the adult snails are large and easily visually detected and removed by hand the much smaller juveniles are much harder to detect particularly if they burrow down into sediments.
1.22. How likely are the biological characteristics of the organism to facilitate its establishment?	very likely	high	*C. chinensis* reproductive strategies greatly facilitate the establishment and continuity of the species. The snail is ovoviviparous giving birth to live, fully developed juveniles (Dillon 2000) and so avoiding the uncertainties of a free-swimming planktonic stage. Female fecundity is high with brood pouches found to contain up to 133 embryos at once (Stephen *et al* .2013); estimates for the number of live young produced annually varies between about 30 (Collas *et al.* 2017) to 65 (Keller *et al.* 2006). Females can start breeding in their first year (Stephen *et al.* 2013) but produce most young during their 4th and 5th years. *C. chinensis* is possibly able to reproduce by parthenogenesis as this is a known reproductive strategy for Viviparidae species (Johnson 1992; Claudi & Leach 2000). If the snail can reproduce parthenogenetically then this will greatly assist in the colonisation of new habitats as a single female snail could, even in the absence of a male normally required for fertilisation, establish a new population of snails (albeit genetically homogeneous). Additional *C. chinensis* biological characteristics likely to assist its establishment in new sites are its ability to withstand a very wide range of temperatures (see

			1.12 above) and prolonged periods of drought; an ability to withstand hot, dry conditions for at least 8 weeks (Havel, 2011; Unstad, 2013).
1.23. How likely is the capacity to spread of the organism to facilitate its establishment?	unlikely	high	*C. chinensis* has limited capacity for unaided spread. Virtually all accounts describing the spread of this species in the USA and Europe attribute this to deliberate, but mostly accidental spread by a wide range of human activities described in the 'entry' (above) and 'spread' (below) sections.
1.24. How likely is the adaptability of the organism to facilitate its establishment?	Very likely	very high	The extreme adaptability of *C. chinensis* is likely to be important in its ability to establish invasive populations. Key factors include: 1. Reproduction (production of large numbers of live young over many years, possibly parthenogenesis) … see 1.22 above. 2. Ability to survive in a remarkably wide range of (a) climatic conditions (see 1.12 above.) and (b) water /abiotic environmental conditions (see 1.13 above) 3. Ability to survive prolonged periods of drought aiding persistence at infected sites and transport to new sites (see 1.21)
1.25. How likely is it that the organism could establish despite low genetic diversity in the founder population?	very likely	very high	There appear to be few studies of the genetic variability of invasive populations which often occur in discrete, isolated 'pockets' (as with the widely dispersed populations now spreading in the Netherlands). It is suspected that low genetic diversity has not acted to inhibit the establishment of founder populations. Genetic research is suggested in '4.1: Additional Questions – Research' below.
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 likely	very high	As documented in Section A: 7 above, *C. chinensis* has already established breeding populations at four sites within the risk assessment area: Pevensey Levels, East Sussex and at sites in/around Southampton, Hampshire.
1.27. If the organism does not establish, then how likely is it that	likely	medium	*C. chinensis* is currently established but in the event of total eradication of all populations in the risk assessment area then recolonisation could occur. This could be from further accidental or deliberate releases of snails imported into the

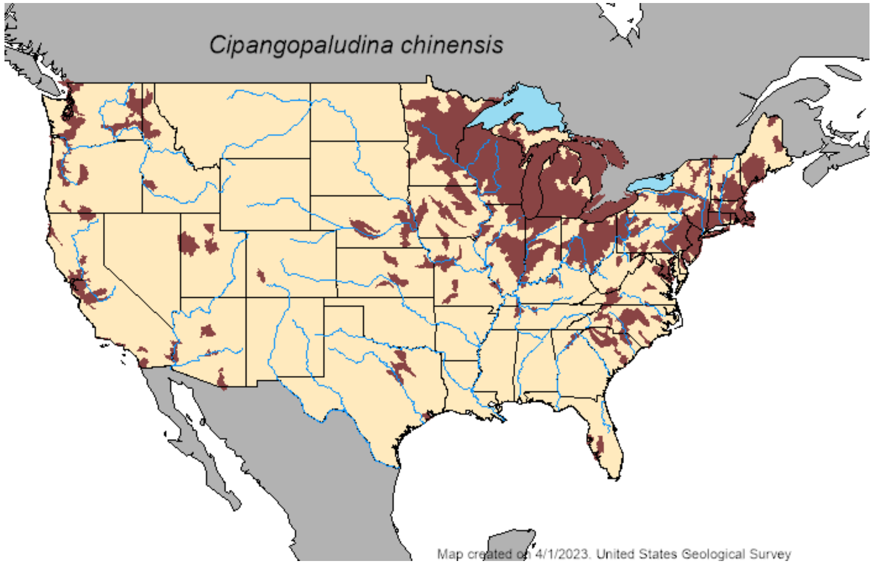
transient populations will continue to occur? Subnote: Red-eared Terrapin, a species which cannot re-produce in the risk assessment area but is established because of continual release, is an example of a transient species.			country for food or more probably for aquaria and garden ponds. Natural entry via waterfowl, although theoretically possible is unlikely (see Entry C1.3 above).
1.28. Estimate the overall likelihood of establishment (mention any key issues in the comment box).	very likely	very high	*C. chinensis* is already established in two widely separated locations and may have been living in the risk assessment area at one of these for at least 7-9 years.

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.)	minor	high	1. Contaminant in animals: There is the theoretical possibility of spread from the currently known infected sites in the risk assessment area by way of ingestion and then later regurgitation by mollusc-eating diving ducks and other waterfowl (discussed in Section C1.3 above). 2. Water corridor (interconnected waterways): There are few studies of *C. chinensis* spread through water bodies or along interconnected waterways; the only located study of the rate of natural dispersal is at Eijuder Beemden by the River Meuse estimated spread at approximately 0.1 km yr-1 (Collas *et al*. 2017). It is estimated that *C. chinensis* have been living in the infested Pevensey ditch since at least 2013 – 2015 (Willing & Jones 2020) and evidence suggests it has spread to only one side ditch in the possible 10 + years that it has been living there (Willing, 2021a, 2021b, 2022a).
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.)	moderate	medium	There are a variety of ways that *C. chinensis* could be spread in the risk assessment area by both deliberate and accidental human assistance. 1. Deliberate release into nature for later use: it is possible that the population at Pevensey Levels resulted from deliberate introduction (see response to A1.3 above), as was suggested in the rapid risk assessment (Willing & Jones 2020). Further introductions like this could spread the species in GB. 2. Deliberate release of aquaria contents: this appears to be the main introduction pathway for this species and will also facilitate its spread in GB (see response to B1.4 above). In addition, at open access sites in GB, such as the two infected ponds on Southampton Common, the collection of these readily seen, large snails by children and others during 'pond-dipping'

			activities is a concern especially if the animals are removed from the area to be introduced into garden ponds or home aquaria. 3. A contaminant on angling equipment and footwear: Contaminated bait buckets, keep nets and other fishing gear together with the soles of angling footwear could all act as potential unintentional transfer routes (especially for the smaller and so more easily overlooked juvenile stages of the snail). It is possible that the snails could have been introduced at two fishing lakes in Southampton by contaminated equipment and by club members travelling between other waters. 4. Associated with movement & transport of boats: this is one of the introduction pathways for *C. chinensis* (see response to E1.3 above) and could also facilitate spread. Evidence for spread by boats is supported by a survey of 21 American lakes where the snail was more likely to be found at sites near boat launches with a decrease in presence with increased distance from such sites (Solomon *et al.* 2010). *C. chinensis* could readily be removed from a site on anchor chains contaminated with bottom sediments. Boat related transfer from the two known GB infested sites is not considered a risk as they are not used for boating or sail boarding etc. The Southampton 'Boating Lake' is believed to be used for model boats and there is a theoretical but unlikely chance of a juvenile snail becoming attached to a model boat and then introduced to another water body if the model boat was launched again within a short period of time. 5. Accidental transport on water channel maintenance machinery: In the Netherlands the maintenance of water channels (by dredging and weed control) and the resulting transfer of dredged materials and the maintenance equipment is considered to be a likely source of secondary spread of *C. chinensis* between and within waterbodies (Matthews *et al.* 2017a). On Pevensey Levels one of the main causes of the rapid spread of invasive plants (e.g. New Zealand Pygmyweed *Crassula helmsii*, Floating Pennywort *Hydrocotyle ranunculoides*) is suspected to be transfer by ditch clearing machinery (K. Jackson, [Natural England] personal communication). It is

			possible that this could also facilitate the transfer of this snail to locations far from the known site, both within and outside the catchment.
2.3. Within the risk assessment area, how difficult would it be to contain the organism?	difficult	high	There has apparently been successful *C. chinensis* containment at the Pevensey Levels site through the installation of coffer dams (see 2.1 above) since its discovery in 2018. It is estimated that the Southampton Common population has been present since 2017 and during that time had the potential to be spread by natural means (e.g., diving ducks and other waterfowl) and also by accidental transfer (e.g. angling activities in the Ornamental Lake) or deliberate spread (e.g. removal for the stocking of garden ponds & aquaria). All such transfers would be difficult to contain but, as of November 2023, Southampton City Council plan to put biosecurity and warning notices (relating to the presence of this invasive species) around the two infected lakes. In the GB risk assessment area, if *C. chinensis* is able to colonise new sites then it seems control will be difficult particularly from open access sites used for fishing, pond-dipping and other activities as the primary route for further introductions (as in continental Europe, see 2.2 above). The future ease of control would depend upon the nature of the newly colonised sites. If these are closed (and the infestation is detected) then it might be possible with education and other restrictions to minimise deliberate and accidental human spread. In open and connected water courses (river catchments and networks of drainage ditches) then natural spread would pose greater difficulties.
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.		very high	The CMS's ability to tolerate a very wide variety of (1) water conditions and (2) ecoclimatic zones means that the snail could theoretically establish in much of the risk assessment area (except perhaps faster flowing upland rivers and streams and acidic or base-deficient ponds lakes, lochs and llyns) (see response to 1.13 above for more detail).
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	0-10	very high	*C. chinensis* is currently only known from two areas (but widely separated) in the risk assessment area: on Pevensey Levels, East Sussex and at a small number of sites in and around Southampton, Hampshire.

already been colonised by the organism?			
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	high	It is estimated that *C. chinensis* has been present at Pevensey Levels for at least 7 – 9 years and in the Southampton Common area for 5 years (see Section A: 7 above). Despite these two potential sources of spread no further populations have yet been reported. If future site infestation proceeds at an equally slow pace, then the snail is predicted to have colonised relatively few new sites within the next 5 years.
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.)	50	low	There has been little detected spread of C. chinensis in the last ten years (probable approximate time of first colonisation); with two widely separated populations now detected, a period of 50 years seems reasonable in which to gauge further significant 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?	>10	low	Within the 50-year time frame it is suggested that rather more than 10% of potentially suitable habitat within the GB risk assessment area is likely to be colonised. The snail may well have been present in the risk assessment area (at Pevensey) since 2013 if not earlier. This species was introduced to western North America in the late 1800s (see response to question A6) and independently in eastern USA in the 1900s. Through a combination of multiple introduction events and natural dispersal it has subsequently spread across an area of the north-eastern United States that spans over 1,000km (Figure 7 below) – including the drainage of the great lakes (Lake Erie, Ontario and Michigan) where it first arrived in the 1930s. In the Netherlands, sites for this species have doubled in the past 6 years (see response to question A6) and are scattered across the country. It is therefore not unreasonable to expect that the Chinese mystery snail could form widely scattered populations across GB in the 50 years following its introduction (as it has done in continental Europe). Where these populations occur, they will spread locally at a (conservatively) estimated rate of perhaps 0.1km per annum (see response to question 2.1), taking many decades to spread along

			waterways. On this basis, it is estimated that >10% of Great Britain could be occupied over a period of 50 years; however, there considerable uncertainty in this assessment.  Fig 7. Distribution of Chinese mystery snail in the USA. Dark red = hydrological units in which this species occurs. Source: https://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=1044
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).	slowly	medium	With an abundance of potentially suitable habitat (particularly in lowland areas such as the bulk of England) within the risk assessment area (see 2.4 above) the long-term potential for future spread is considerable. For example, within the United States *C. chinensis* has managed to occupy 36 States since its probable introduction there at the end of the 19th century (a period of about 130 years). In NW Europe it has colonised at least 27 sites in Belgium and the Netherlands since first discovered in 2007 and since 2020 has been detected as single populations in Germany and Spain. The NW European sites consist of both clusters and widely separated nuclei (see Fig. 1 above). Most studies in both the States and in Europe have suggested that spread of the snail has not significantly

			resulted from natural processes but rather by deliberate and unintentional human activities (as documented in various boxes above).

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	high	Despite being present in the USA for about 140 years and with a distribution extending over at least 36 states evidence for negative economic impact is slight (Matthews *et al.* 2017). It is suggested that the shells may clog the screens of water intake pipes (AIS 2005, Kipp *et al.* 2014). At high densities the snail can clog fishing nets and so impede or reduce fish catch (Global Invasive Species Database 2011; Hanstein 2012). The snail has been known in Europe since 2007 and there are, as yet, no significant reports of negative economic impacts due to the snail. Large *C. chinensis* populations have been reported to cause nuisance by littering the shores of water bodies in the USA with dead and decaying snails (Bury *et al.* 2007). Similarly, there is also a concern that in the Netherlands, decaying dead snails on the shores of the Eijsder Beemden may cause a decline in the recreational summer usage of a popular site (Collas *et al.* 2017). No current management costs have been obtained. Similarly, Matthews *et al.* (2017) state, "*The economic costs associated with the management of C. chinensis in the EU in the past and future are unknown. Estimations of the total cost of management efforts for the EU and North America are not available*".
2.11. How great is the economic cost of the organism **currently** in the risk assessment area **excluding**	minimal	very high	The CMS populations currently known to be living in the GB risk assessment area (Pevensey Levels & Southampton area) have not yet resulted in any economic costs or losses.

management costs (include any past costs in your response)?			
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	high	It is not yet possible to estimate the potential economic costs in the GB risk assessment area but, judged on the minimal negative economic impact in the USA (where the snail has been present for 140 years and is now living in at least 36 States), economic costs are projected to be minimal.
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)?	minor	very high	It is estimated that the costs of surveying, monitoring and installation of coffer dams to contain the snail at the Pevensey Levels ditch was £80-100K. Natural England has used staff time to survey the Southampton sites and there will be a cost associated with the manufacture and placement of warning/biosecurity notices around the sites there; the level of cost is unknown.
2.14. How great are the economic costs **associated with managing** this organism likely to be **in the future** in the risk assessment area?	minor	high	Future management costs are not possible to estimate because these will depend upon the effectiveness of detection and control measures of few populations of the snail. There are no known *C. chinensis* management /eradication operations for the European populations and so economic management costs past and future are unknown (Matthews *et al*., 2017).
2.15. How important is environmental harm caused by the organism within its existing geographic range **excluding the risk assessment area**?	medium	low	Matthews *et al* (2017) provide an extensive review of impacts from across this species global range, much of which is included in the following summary. In a mesocosm outdoor experimental system *C. chinensis* was found to have a negative effect upon two north American water snails (one of which, *Lymnaea stagnalis* is found in the UK) possibly due to food competition (Johnson *et al.* 2009). These declines were further increased in the presence of various crayfish species in a series of complex interactions depending upon the crayfish species. A further experiment in Washington suggested that the presence of *C. chinensis* may aid in the establishment of one species of invasive crayfish by providing an abundant food source (‘invasional meltdown’), but the hypothesis required further testing (Olden *et al.* 2009). However, such experimental negative impacts on native gastropod assemblages have not yet been confirmed in field studies. Solomon *et al.* (2010) found *C.*

			chinensis to be widespread in 21 lakes studied in Wisconsin but found that there was no overall difference in snail assemblage structure at the sites as a function of *C. chinensis* presence or abundance. Although lake occurrences of many snail species had apparently been lost over time there, a comparison to a 1930s survey data showed that there was no increased likelihood of species loss in lakes invaded by the snail. In other laboratory studies it has been noted that the filtration rate of *C. chinensis* is comparable to a number of highly invasive freshwater bivalves (e.g. *Dreissena polymorpha*), which may result in impacts due to filtration of phytoplankton. It may also give the snail a competitive feeding advantage to other filter feeders (Olden *et al.* 2013). In a further mesocosm experiment *C. chinensis* feeding was found to reduce algal biomass, algal species composition and increase the N:P ratio in the water. Such effects may have important ecological results which require further study (Johnson *et al* 2009). Possibly linked to the former changes *C. chinensis* presence slightly alters the microbial community (Olden *et al.* 2013). Overall, Matthews *et al* (2017) conclude that the probability of environmental impact in the Netherlands is medium because of the experimental evidence available. However, this is given with low confidence because it has not been confirmed by field data and there is uncertainty over the likely density of populations that will occur in the Netherlands. Based on the evidence above, the importance of environmental harm caused by this species in its existing geographic range is considered to be potentially medium with low confidence. This is similar to the risk assessment performed for the Netherlands (Matthews et al 2017), the draft EU risk assessment (Lucy and Davies 2022) and the New York invasiveness risk assessment (Adams and Schwartzberg 2013).
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	minimal	very high	*C. chinensis* has not led to any detected biodiversity loses or changes at its known GB risk assessment zone sites. There is no known freshwater survey data for the pre-infestation period for the infested Southampton sites. At Pevensey, the infested part of the ditch no longer supports the protected *A. vorticulus* but as this was last

assessment area (include any past impact in your response)?			detected (in this stretch of the ditch) in 2006 it may have been lost from the ditch prior to its' colonisation by the CMS.
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	Evidence from elsewhere (Matthews *et al* 2017) indicates that this species could reduce native snail populations through competitive exclusion, altering nutrient cycles and decreasing algal biomass; however, these impacts have not yet been demonstrated in the field (see response to Q.2.15). As *C. chinensis* is a facultative filter-feeding detritivore (Olden et al 2013) then it is likely to compete with not only native facultative filter-feeding gastropods like *Viviparus viviparus* & *V. contectus* but native obligate filter feeding unionid mussels (e.g. *Anodonta cygnea*, *A. anatina*). There is also a risk that the species could alter ecosystems through high rates of filtration, similar to the zebra mussel. The extent of impact may be determined by the population density achieved, which appears to be higher in continental Europe than in North America (Matthews et al 2017). It is reasonable to expect that these impacts may occur in GB and that the impacts here will be similar to those anticipated for the Netherlands. In the Netherlands this species is spreading into regions designated for their conservation importance – and this is also the case for GB. On the Pevensey Levels if *C. chinensis* spreads from its sole source ditch it has the potential to disrupt the rich and extensive freshwater ditch ecosystems on Pevensey Levels. This area is a 3.6K hectare biological SSSI, Ramsar site, supports a National Nature Reserve; it is nationally and internationally important for supporting many rare invertebrates; it is one of the best sites in the UK for a variety of rare freshwater Mollusca (Anon 2013) including the Little Whirlpool Ram's-horn Snail *Anisus vorticulus* https://sac.jncc.gov.uk/species/S4056/. This snail is listed 9 on the European Union Habitats and Species Directive (EUHSD) Annexes IIa and IV (strict protection) and is also an English NERC (2006) Section 41 Species of Principal Importance in England and assessed on the latest UK Status Review as 'Vulnerable' (Seddon *et al*. 2014). Pevensey Levels is one of three Special Areas of Conservation (SAC) designated for the snail in England. The spread of *C. chinensis* throughout Pevensey Levels is of concern as its impact on *A. vorticulus* and indeed other rare molluscs (e.g. *Valvata macrostoma* & *Segmentina nitida*) and invertebrates living there is unknown. By the time any damaging impact is detected then control of the invasive would probably be difficult and expensive.

			There are suggestions that in the USA *C. chinensis* populations might facilitate the establishment and / or improve the establishment success of invasive crayfish such as Signal Crayfish *Pacifastacus leniusculus* (Olden *et al*. 2009). The potential abundance of additional and easily caught prey provided by *C. chinensis* might act to assist the maintenance and/or further spread of invasive *P. leniusculus* in the risk assessment area. *P. leniusculus* is already suspected of being a successful predator on a wide range of native freshwater gastropods in the upper Thames catchment (Rowson *et al.* 2021).
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	medium	*C. chinensis* has not led to any detected ecosystem functional changes at its known GB risk assessment zone sites.
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	high	There is little evidence from the USA (where *C. chinensis* has been present for about 140 years and is now widespread especially in the north-eastern States, that closely resemble the ecoclimatic conditions in the GB risk assessment area) of *C. chinensis* leading to any ecosystem changes. As stated in 2.15 above *C. chinensis* can efficiently filter feed. If the snail occurs in high numbers, this might give it a competitive feeding advantage over other filter feeders (Olden *et al*. 2013). It might therefore outcompete native filter feeding mollusc such as *Viviparus* spp, *Unio* spp and *Anodonta* spp.
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	*C. chinensis* presence has led to no detectable decline in the conservation status of the two designated sites (Pevensey Levels SAC, Southampton Common SSSI) that it currently occupies in the GB risk assessment 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?	moderate	medium	*C. chinensis* has already demonstrated its ability to establish in sites designated for their conservation importance in GB and continental Europe, including sites with important native snails present. As discussed in 2.17 above, *C. chinensis* has the potential to cause a decline in rare, threatened and endangered freshwater Mollusca on Pevensey Levels. Similarly, if the snail were to colonise other similar lowland and coastal grazing marsh such as the Arun Valley, the Somerset Levels and Norfolk Broads also supporting molluscan communities of conservation importance, then it might equally have a negative effect upon them.
2.22. How important is it that genetic traits of the organism could be carried to other species, modifying their genetic nature and making their economic, environmental or social effects more serious?	minimal	high	There is no evidence of any actual or potential genetic transfer from *C. chinensis* to any other species (the most likely in the GB risk assessment zone being the two native *Viviparu*s spp also members of the Viviparidae).
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	very high	In its native Asian range *C. chinensis* is a host for several platyhelminth parasites that affect man such as human intestinal fluke (Chung & Jung 1999, Havel 2011, NAPIS 2010) but, throughout its now extensive invasive range in the USA, there have been no reported cases of transmission (Bury *et al.* 2007). There is therefore no evidenced based reason to believe that this risk will exist in Britain.
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	low	Food: If *C. chinensis* can colonise suitable habitats resulting in the formation of sizeable populations then these might act as a potential food resource for a variety of species including some considered to be undesirable pests. The closely related native *Viviparus viviparus* has been shown, when present in large numbers, to act as a food resource for brown rats *Rattus norvegicus* (Gordon *et al.* 2016). It is suggested that *C. chinensis* might equally provide a similar food source particularly (except perhaps in winter months) as it tends to be plentiful and visible in shallow marginal areas of ponds and ditches. Host / vector: See 2.23 above.

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	NA
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?	minor	medium	1. <u>Food source</u>: As discussed in 2.24 above large *C. chinensis* populations could act as food resources for a variety of species including brown rats and corvids such as carrion crows (*Corvus corone*). 2. <u>Environmental</u>: The most serious immediate potential impact is to the Pevensey Levels SAC grazing system. As stated in 2.27 below other similar areas are at potential risk if the snail can spread throughout the GB rick assessment area.
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).	refer to comment	medium	As discussed in 2.17 & 2.21 above, the most immediate threat is judged to be to some of the molluscan and other invertebrate features of the Pevensey Levels SAC, which is judged to one of the most important wetland systems in GB. Equally if *C. chinensis* spreads more widely then it poses an equal threat to similar wetland systems of conservation importance such as the Arun Valley, the Somerset Levels, Gwent Levels and the Norfolk Broads.
2.28. Estimate the overall impact of this organism in the risk assessment area (using the comment box to indicate any key issues).	moderate	medium	In summary, most generalised negative environmental impacts are projections based upon various experimental studies rather than documented reports of actual damage in the wild. It has also been pointed out that environmental impact of *C. chinensis* in North America is widely described as limited, but this should be set against a situation where species densities for the snail there are claimed to be low. There are however observations of seemingly high population densities in North America. Matthews et al 2017b notes that "In Minnesota, USA, dead and decaying shells have become a nuisance to local residence because they wash up on shores in high abundances (Bury et al., 2007). In the Laurentian Great Lakes of North America, fisherman have previously complained of making large hauls containing "2 tons" of snails in dragnets, which were likely B. chinensis or B. japonica (Wolfert & Hiltunen, 1968)". Such observations might indeed suggest that C. chinensis can occur at high population levels in the USA. The potential for impact when the snail is present at higher densities (as seems to be the case for some of the Dutch sites and for the Pevensey Levels site) are largely unknown (Matthews *et al.*

			2017a, 2017b). *C. chinensis* has the potential to cause wide-scale disruption to the ecosystems of the Pevensey Levels and thereby possibly endanger rare and protected species such as *Anisus vorticulus*. The overall environmental impact of the snail in Europe has been assessed as 'Medium' (Matthews *et al.* 2017b) and this is the assessment for the UK, although on a local scale the impact could, in a 'worst-case' situation, be 'Major' if the snail reaches the high population levels that have generally not been recorded in North America. In the United States the overall risk has been categorised as 'High' based chiefly upon the snail's (1) history of invasive success, (2) climate matching to much of the country, (3) experimentally demonstrated ability to depress or exclude some native water snails and (4) the potential to block water pipes and cause a 'nuisance' on lake shores (Anon. 2018).

RISK SUMMARIES			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	very likely	very high	Potential entry routes into the risk assessment area were considered. Natural movement with birds, introduction as a contaminant of imported plants and contamination of angling equipment were assessed as very unlikely. Introduction with boats / shipping was considered unlikely. The most likely entry pathway for further introductions was introduction for the aquarium trade and / or food consumption. The accidental or deliberate release of *C. chinensis* both directly and indirectly relates to the commercial import of the snail.
Summarise Establishment	very likely	very high	*C. chinensis* has already established breeding populations at four sites in the risk assessment area and may have been present at one since at least 2013. The snail's remarkable adaptability in terms of being able to live in (1) a very wide range of ecoclimatic zones (particularly successfully the Atlantic Biogeographical Region), (2) to exist in a wide variety of water conditions, (3) to employ a range of successful and certain reproductive strategies and (4) to tolerate a prolonged period of drought means that it has the potential if introduced, to successfully colonise numerous freshwater habitats throughout lowland GB.
Summarise Spread	slowly	medium	Although there are several potential *C. chinensis* natural spread pathways (e.g. via animal vectors like waterfowl) these have not been demonstrated by reliable evidence. The few studies of spread via natural corridors (e.g. inter-connected waterways) show very slow colonisation. The primary cause of spread into new areas in both the USA and Europe is widely suggested (although unequivocal evidence-based data is lacking) to be by human facilitated means. In the USA there is some data to show that the snail can be spread as a transport contaminant on boats but accidental transfer by angling activities although theoretically possible has not been demonstrated. The possibility of spread within and beyond infested areas by way of contaminated water channel machinery has been suggested in Europe and GB. The accidental and / or deliberate release of the snail resulting from the aquarium and garden pond trade is seen as the primary source of spread in Europe. The ability of *C. chinensis* to survive for several months out of water gives it considerable potential for accidental release far from the point of contamination.

Summarise Impact	moderate	medium	Despite the widespread and long-term presence of *C. chinensis* in the USA there is only slight evidence of negative social, economic and environmental effects there. Although a vector for various diseases in its native range these have not been demonstrated in its invasive range in America and Europe. Similarly economic impacts such as a reported clogging of water pipes are not proven. Although the snail's presence has been shown to have a negative effect upon a couple of native American water snails, field studies at a lake level have not detected significant adverse effects upon molluscan communities there. Most generalised negative environmental impacts are projections based upon a few experimental studies rather than detected damage in the wild. In the risk assessment area *C. chinensis* has the potential to cause widescale damage to the protected and nationally important Pevensey Levels SAC (and other similar wetland grazing systems elsewhere in GB) thereby possibly endangering a range of rare and protected species such as *Anisus vorticulus*.
Conclusion of the risk assessment	medium	medium	In conclusion it is pertinent and appropriate to include some edited statements from Collas *et al.* (2017) which relate to the introduction and spread of *C. chinensis* in Europe. "*The greatest risk for dispersal of C. chinensis results from human-mediated activities …. The aquarium trade is an especially important pathway for C. chinensis …"*

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?	If the average temperature of Great Britain increases by a few ^{o}C it is not believed to significantly affect the invasive risk posed by *C. chinensis*. Climate change/global warming not only increases the mean and extreme summer temperatures, but may, by causing significant disruption to weather patterns, also possibly result in periods of lower-than-average winter temperatures and periods of flooding and drought. Slightly contradictory evidence is available regarding the temperature parameters tolerated by *C. chinensis.* It is stated that it is a temperate species with a lower limit of 0 ^{o}C and an upper limit of 30 ^{o}C (Kipp & Benson 2008 in Karatayev *et al* 2009). By contrast, more recent studies (Burnett *et al* 2018) which tested the temperature tolerance parameters of wild caught *C. chinensis*, found the snail to have an upper lethal limit ranging between 40 – 45 ^{o}C with complete mortality before 50 ^{o}C. Additionally, despite exposing the snail to extended periods of freezing they did not determine a lower lethal limit. It may be instructive in assessing the consequences of climate change in Britain to study the snail's current invasive range in the United States. Here it is living in 36 States spread across the Union and covering a wide range of ecoclimatic zones. It is suggested that in many of these, in contradiction of the upper limit stated by Kipp & Benson but reinforcing the work of Burnett *et al.* 2018, it survives occasional summer temperatures >30 ^{o}C, these are likely to occur in the mid-west States lying to the south-west of the Great Lakes and may also be experienced in Florida, Hawaii and southern States. Similarly, and again questioning Kipp & Benson's assertions but further supporting those of Burnett *et al.*, *C. chinensis* has a lower temperature tolerance than 0^{o}C; winter temperatures in the Great Lakes region and in north-western States such as New York State frequently fall significantly below this point although this area supports the bulk of *C. chinensis* populations in the States (see USGS map in Kipp *et al* 2020). Rixon *et al.* (2005) supports this view noting that *C. chinensis* is one of few mollusc species predicted to survive Great Lakes winters that experience prolonged temperatures well < 0^{o}C. As well as raising temperatures, climate change may also lead to increasing drought episodes. These might have little negative effects on established *C. chinensis* populations as it can withstand (as adult snails) hot dry conditions for at least 8 weeks (Havel 2011, Unstad *et al* 2013). Such drought periods might give the snail a competitive advantage over many native species which may be less resilient. In conclusion: In view of these observations, it is suggested that future temperature rises in Great Britain are unlikely to have a significant negative impact upon the invasive potential of *C. chinensis* which is a 'temperature hardy' species. They might, however, assist the species if it is shown to have a competitive advantage over some native taxa in conditions of higher temperatures and/or drought.
3.2. What is the likely timeframe for such changes?	Timeframes for climatic change are notoriously difficult to predict and will depend upon international governmental actions to reduce CO2 and CH4 emissions. As these are subject to numerous uncertainties then predicting timeframes for temperature rise and associated droughts does not seem possible.

3.3. What aspects of the risk assessment are most likely to change as a result of climate change?	As discussed above, increased temperatures and the frequency and severity of drought periods might have an effect upon *C. chinensis* establishment success. If such changes give this invasive a competitive advantage over some native mollusc species this would have a bearing on impact if some native species consequentially decline where they occur together with *C. chinensis.*
ADDITIONAL QUESTIONS – RESEARCH	
4.1. If there is any research that would significantly strengthen confidence in the risk assessment, please summarise this here.	1. Captive laboratory studies might assist in getting a better understanding of the interaction of various native molluscan species with *C. chinensis.* 2. DNA sequencing of material from the two GB sites (and also from any further new populations) might help to determine their possible origins and so assist in understanding the snail's entry to the risk assessment area. 3. Collas *et al* (2017) provide some general research suggestions thus, "*future research should focus on gaining data and mechanistic understanding of the species' dispersal processes, ecosystem alterations and impacts upon human health and domestic animals*".

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

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