RISK ASSESSMENT SUMMARY SHEET

Atlantic oyster drill (*Urosalpinx cinerea*)

- A conical marine mollusc, up to 4 cm high and 2 cm broad, with a sharply pointed spire and whorls with pronounced ridges and ribs.
- Native to the Atlantic coast of North America from Cape Cod to south-eastern Florida.
- Introduced with aquaculture stock, but natural spread is slow because a free-swimming larval stage is absent.
- Potentially serious impacts as a predator of native and commercially grown oysters, as well as a competitor with native species.


Bill Frank, www.jaxshells.org

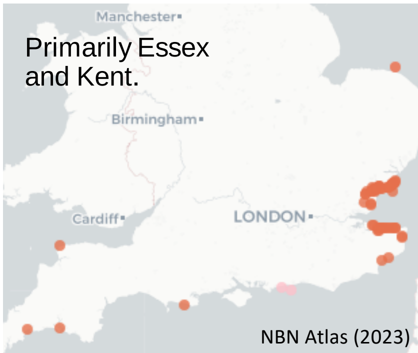
History in GB

First reported in Essex oyster beds in 1927, apparently introduced with oyster stock imported from the US. Subsequently found in estuaries of the rivers Colne, Blackwater, Crouch and Roach and in Kent. The species has also been reported on the Dorset coast (2010), on the south cost of Cornwall (2020), the north and south cost of Devon (2017, 1998 respectively) and off the cost of Norfolk (2011).

Global Distribution


GBIF (2023)

GB Distribution



NBN Atlas (2023)

Impacts

Environmental (moderate, low confidence)

- Through predation on mollusc species, including oysters, *U. cinerea* is known to impact ecosystem functioning.

Economic (minor, low confidence)

- Economic losses may be incurred through loss of commercial shellfish stocks; it has been estimated that a single oyster drill can consume about 40 oyster spat per year.
- Oyster spat loss of up to 75% have been documented for Essex .
- Further costs may occur as a result of loss of other commercial species but also indirectly, e.g. through loss of ecosystem services.

Social (minimal, low confidence)

- None known.

Introduction pathway

Contamination of shellfish stock (particularly oysters) with *U. cinerea* egg cases or small juveniles, and even adults.

Spread pathway

Natural (minor, high confidence) no free swimming larval stage. Adults moved a maximum of 4m from their origin over 8 months in a pilot mark-recapture study.

Human (moderate, high confidence) movement of aquaculture stock.

Summary

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

GB NON-NATIVE ORGANISM RISK ASSESSMENT SCHEME

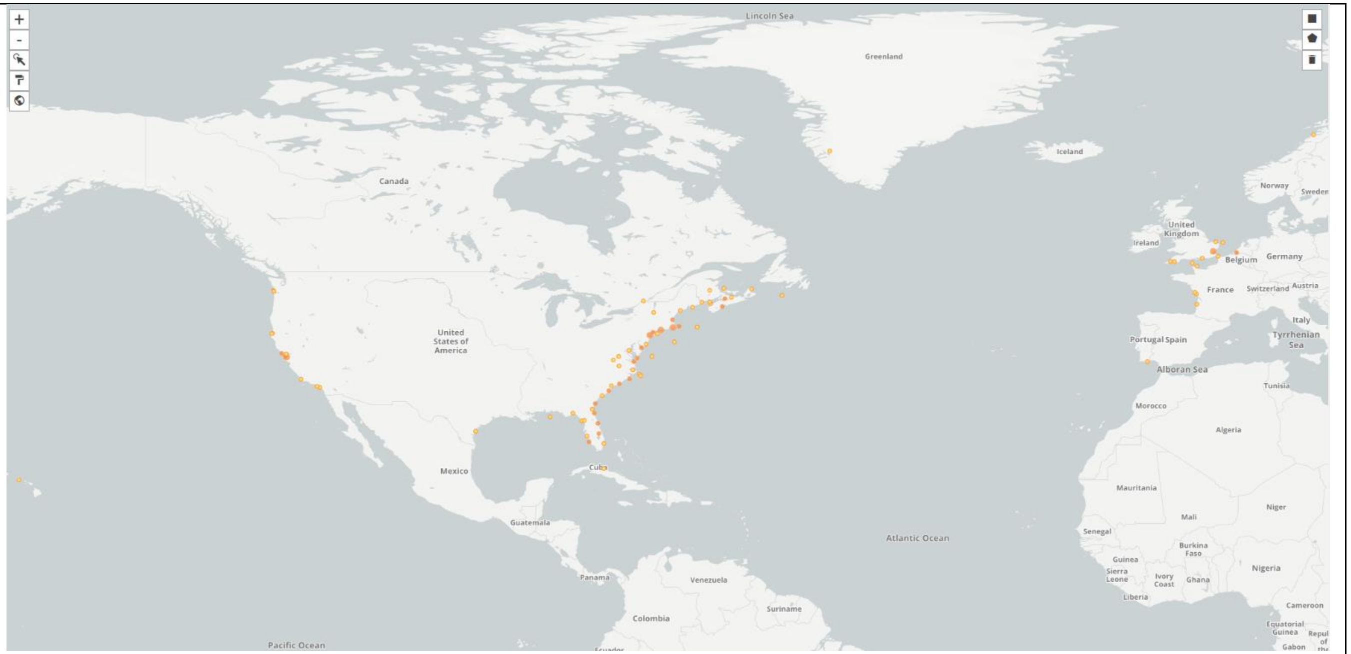
Name of organism: *Urosalpinx cinerea*, Atlantic oyster drill
Author: Hannah Tidbury, Cefas
Risk Assessment Area: Great Britain
Version: Draft 1 (Feb 2023), Peer review (Feb 2023), NNRAF 1 (Mar 2023), Draft 2 (Jun 2023), NNRAF 2 (Oct 2023), Draft 3 (Oct 2023)
Signed off by NNRAF: October 2023
Approved by GB Committee: January 2024
Placed on NNSS website: January 2024

What is the principal reason for performing the Risk Assessment?

The GB Committee for non-native species is considering whether to add this species to the list of species of special concern. This species was selected for consideration following consultation with GB government agencies.

SECTION A – Organism Information	
Stage 1. Organism Information	**RESPONSE**
1. Identify the organism. Is it clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?	Yes *Urosalpinx cinerea* (Say, 1822) Animalia (Kingdom); Mollusca (Phylum); Gastropoda (Class); Caenogastropoda (Subclass); Neogastropoda (Order); Muricoidea (Superfamily); Muricidae (Family); Ocinebrinae (Subfamily); *Urosalpinx* (Genus); *Urosalpinx cinerea* (Species).
2. If not a single taxonomic entity, can it be redefined? (if necessary use the response box to re-define the organism and carry on)	NA
3. Does a relevant earlier risk assessment exist? (give details of any previous risk assessment)	Yes Rapid Risk Assessment for GB (https://www.nonnativespecies.org/assets/Uploads/Urosalpinx_cinerea_final_for_website.pdf), the summary scores of which are: • Entry – very likely (very high confidence) • Establishment – very likely (very high confidence) • Spread – slow (medium confidence) • Impact – major (medium confidence) • Overall risk – high (medium confidence)
4. If there is an earlier risk assessment is it still entirely valid, or only partly valid?	Partially Last updated July 2018 and only a rapid risk assessment.

5. Where is the organism native?	Atlantic coast of north America The native range of *U. cinerea* is the Atlantic coast of North America from the Gulf of St Lawrence to Southeastern Florida (Cohen, 2011 and references therein).
6. What is the global distribution of the organism (excluding the risk assessment area)?	Introduced into West (Pacific) coast of North America and Europe. **North America** *U. cinerea* has been introduced to the Pacific coast of North America, initially reported in San Francisco Bay in 1890 (Cohen, 2011). **Europe** • **France:** This species was found in France between 1960 and 1969, though establishment did not occur there (Cohen, 2011 and references therein). • **Netherlands:** In 2007, *U. cinerea* was recorded in the Netherlands, where it established a self-sustaining population (Faasse, 2009; Faasse & Ligthart, 2007). • **Portugal**: Recent records also indicate that the species was found for the first time in Portugal in 2021 (iNaturalist, 2022)

	 Figure 1. Global *Urosalpinx cinerea* distribution. Accessed from GBIF ([Occurrence search (gbif.org)]) on 08/06/23.

7. What is the distribution of the organism in the risk assessment area?	Southern regions of the risk assessment area. *U. cinerea* was reported in Essex oyster beds in 1927 and then subsequently in estuaries of the rivers Colne, Blackwater, Crouch and Roach and in Kent: mouth of the River Swale (Cohen, 2011; Hancock, 1954 and references therein). The species has also been reported on the Dorset coast (2010), on the south cost of Cornwall (2020), the north and south cost of Devon (2017, 1998 respectively) and off the cost of Norfolk (2011) (see figure 2).  Figure 2. *Urosalpinx cinerea* distribution. Access from NBN Atlas (https://species.nbnatlas.org/species/NBNSYS0000188203) on 12/12/22.
8. Is the organism known to be invasive (i.e. to threaten organisms, habitats or ecosystems) anywhere in the world?	Yes *U. cinerea* is a generalist consumer that can have significant negative impacts on native communities as well as commercial oyster fisheries and aquaculture (Buhle & Ruesink, 2009; Cheng & Grosholz, 2016; Kimbro et al., 2009). In its invasive range, *U. cinerea* can virtually eliminate native oysters and other native species such as mussels and clams via predation (Carriker, 1955; Cheng & Grosholz, 2016; Kimbro et al., 2009). In 1953 in Essex, 55-58% of the oyster spat settling on oyster beds were destroyed by *U. cinerea* following its introduction (Hancock, 1954) However, only 10% of adults of 3 years of age were taken by *U. cinerea* (Hancock, 1954) suggesting that the risk of predation decreases with increasing oyster size.
9. Describe any known socio-economic benefits of the organism in the risk assessment area.	Destruction of heavy spatfall from co-occuring species on oysters by oyster drills may increase marketability, since oysters covered in heavy spatfall are difficult to sell (Carriker, 1955). *U. cinerea* may also predate on Pacific oysters, mitigating their impact on native communities (Faasse, 2009).

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)	very few	high	One active pathway. The primary vector of translocation of *U. cinerea* is transfer of commercial shellfish, in particular oysters (Buhle & Ruesink, 2009; Cohen, 2011; Cole, 1942; Eno, 1996; Faasse & Ligthart, 2007). Introduction of *U. cinerea* into GB waters is thought to have occurred as a result of import and laying of contaminated American Atlantic Oyster (*Crassostrea virginica*) in Brightlingsea and West Mersea in the early 1900s (Hancock, 1954). Due to the lack of a pelagic phase in its lifecycle, there is reduced risk of translocation of *U. cinerea* via natural means (Fey et al., 2010). Live shellfish imports into GB waters still occur, with 50 Pacific oyster consignments, comprising well over 50 million animals, imported for breeding and relaying purposes by sites in England and Wales alone, in 2021 & 2022 (Fish Health Inspectorate for England and Wales 2023, personal communication).
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.	Transport – Contaminant: Aquaculture stock movements		

For each pathway answer questions 1.3 to 1.10 (copy and paste additional rows at the end of this section as necessary).			
Pathway name:	Transport – Contaminant: Aquaculture stock movements		
1.3. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)? (If intentional, only answer questions 1.4, 1.9, 1.10, 1.11)	accidental	very high	There is no doubt that entry along this pathway is accidental.
1.4. How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year? Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place.	unlikely	medium	Contamination of shellfish stock with *U. cinerea* egg cases or small juveniles, and even adults, may go undetected, though biosecurity measures may reduce risk of contamination (UK Government, 2023). *U. cinerea* is commonly found attached to shellfish on which they prey such that contamination of shellfish stock coming from locations where *U. cinerea* are present is likely, though the species is not widespread globally. Shellfish imports into GB waters still occur, with 50 oyster consignments, comprising well over 50 million animals, imported by sites in England and Wales alone, in 2021 & 2022. The origin of imports are primarily Guernsey, Jersey, Ireland and France. Imports from France may be from areas in close proximity to locations where *U. cinerea* has been reported though due to the nature of hatchery systems, risk of contamination is likely to be low. Also, consignments are Health Certified which requires that they are checked and comprise the declared species only, further reducing risk of obvious contamination (Fish Health Inspectorate for England and Wales 2023, personal communication). However, it is noted that Health Certification, and associated checks, is a mechanism to minimise the risk of introduction of Aquatic Animal diseases rather than invasive species.

1.5. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)?	likely	high	Transfer of this species into new locations, through contamination of aquaculture stock is documented (Faasse, 2009), indicating that survival of passage along this pathway is both possible and probable. Though possible it is unlikely that the species would multiply along the pathway, especially given its short duration.
1.6. How likely is the organism to survive existing management practices during passage along the pathway?	moderately likely	medium	Generic biosecurity such as careful inspection and cleaning of shellfish stock will reduce risk of *U. cinerea* transfer via this pathway. Freshwater treatment, while effective for destroying some invasive species associated with shellfish and therefore recommended as part of robust biosecurity measures (e.g. Carman et al., 2016; Denny, 2008), is not effective at reducing the risk of *U. cinerea* transfer on shellfish (Brink & Wijsman, 1993).
1.7. How likely is the organism to enter the risk assessment area undetected?	likely	high	Egg cases (4-5 mm) and juveniles are small and difficult to detect (Fey et al., 2010). Entry of organisms via this pathway undetected has occurred historically, however, raised awareness and improved biosecurity (e.g. inspection of stock) in the shellfish sector may reduce the risk likelihood of subsequent entry.
1.8. How likely is the organism to arrive during the months of the year most appropriate for establishment?	likely	medium	Reproduction occurs in the spring and summer when water temperature increases. Cole (1942) reported that spawning occurs as temperatures increase to above 12°C. In British waters specifically, egg laying was documented in May and June, though freshly laid capsules were also found in August (Cole, 1942). After approximately 6-8 weeks young emerge from the eggs and begin feeding on various shellfish species, primarily oysters. Individuals can live for up to eight years (Cohen, 2005). Shellfish movements for aquaculture are primarily made during spring and summer months (Fish Health Inspectorate for England and Wales 2023, personal communication), when conditions are optimum for reproduction. Establishment of

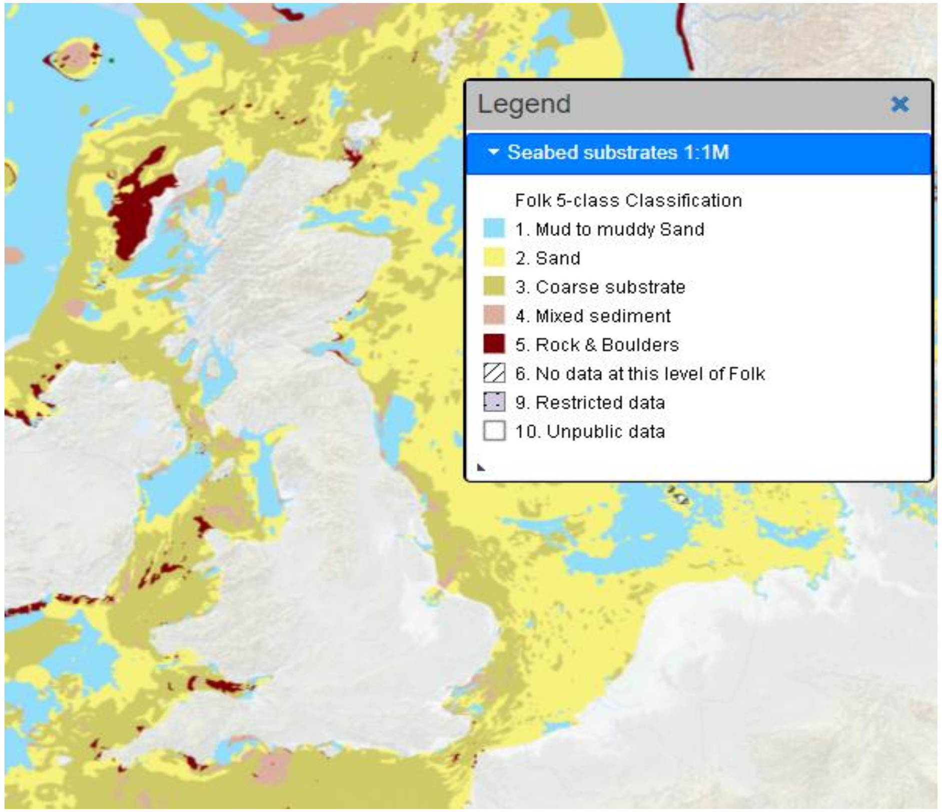
			the species following entry of sexually mature adults via this pathway is therefore likely. Entry of the species as early life history stages, such as egg capsules or juveniles, may also occur via this pathway. Establishment will depend on the animals surviving until sexual maturity (age 1-2 years) (Fey et al., 2010).
1.9. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	very likely	very high	Entry via this pathway (i.e. attached to shellfish) means entry into suitable habitat with available food (see section 1.15 for further details on suitable habitat).
1.10. Estimate the overall likelihood of entry into the risk assessment area based on this pathway?	moderately likely	medium	Introduction of *U. cinerea* into GB waters is thought to have occurred as a result of import and laying of contaminated American Atlantic Oyster (*Crassostrea virginica)* in Brightlingsea and West Mersea in the early 1900s (Hancock, 1954). The origin of current imports are primarily Guernsey, Jersey, Ireland and France. While imports from France may be from areas in close proximity to locations where *U. cinerea* has been reported, hatcheries are often isolated from the marine environment, reducing the risk of contamination of stock. Further, consignments are Health Certified which requires that they are checked and comprise the declared species only, further reducing risk of obvious contamination (Fish Health Inspectorate for England and Wales 2023, personal communication).
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	Introduction of *U. cinerea* into GB waters is thought to have occurred as a result of import and laying of contaminated American Atlantic Oyster (*Crassostrea virginica)* in Brightlingsea and West Mersea in the early 1900s (Hancock, 1954). The origin of current imports are primarily Guernsey, Jersey, Ireland and France. While imports from France may be from areas in close proximity to locations where *U. cinerea* has been reported, hatcheries are often isolated from the marine environment, reducing the risk of contamination of stock. Further, consignments are Health Certified which requires that they are checked and comprise the declared species only, further reducing risk of obvious contamination (Fish Health Inspectorate for England and Wales 2023, personal communication).

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
1.15. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in the risk assessment area?	widespread	high	*U. cinerea* inhabits intertidal and shallow subtidal waters in bays, estuaries and marshes to a depth of approximately 15m. This species is found in oyster beds, muddy substates (Cole, 1942) and rocky areas (Cohen, 2005) which are widely distributed around the risk assessment area (see Figure 3). *U. cinerea* feeds on oysters, barnacles, mussels and other small molluscs (Cohen, 2011; Faasse, 2017) which are widely distributed around the risk assessment area. *U. cinerea* is very tolerant of a wide range of environmental parameters, in particular temperature and salinity. For example, survival in temperature ranges from -1 up to 25° C have been reported (Faasse, 2009), though a minimum temperature of 9-10 °C is required for *U. cinerea* to feed, with temperature and feeding rate found to be positively correlated. A temperature >12°C is required for spawning (Cohen, 2011; Faasse, 2017; Hancock, 1954). Egg development time varies with temperature. The optimum temperature range for egg development is 20-25°C, though development occurred at 10°C, hatch rate was reduced to 65%. No development occurred at 7.5°C (Ganaros, 1958). A salinity range of 15-37 ppt has also been documented (Brink & Wijsman, 1993; Cohen, 2011; Faasse, 2017 and references therein). In a study testing the impacts of salinity and temperature, *U. cicerea* remained active from 12.5-26.5 ppt, though egg laying did not occur at salinities of 15 ppt or lower. Interaction between temperature and salinity on feeding and survival has been noted (Manzi, 1970).

			 Figure 3. Sea bed substrate type map at scale 1:1,100,100, accessed from the European Marine Observation and Data Network (EMODnet) (https://www.emodnet-geology.eu/map-viewer/?bmagic=y&layers=emodnet_substrate_250k) on 08/12/2022. Environmental conditions suited to *U. cincerea* species are present in the risk assessment area. Though temperature dependancies will likely increase the probability of establishment within sourthern areas of the risk assessment area. The presence of *U. cinerea* within the risk assessment area further supports the suitability of the risk assessment area for the species.

			Individual longevity, a wide range of prey species, frequent reproduction, with relatively high fecundity, and wide environmental tolerances, increase the likelihood of this species' establishment.
1.21. How likely is it that biological properties of the organism would allow it to survive eradication campaigns in the risk assessment area?	likely	high	*U. cinerea* is not a broadcast spawner, rather it lays benthic egg capsules from which fully formed young emerge (Carriker, 1955). This trait limits dispersal, reinvasion and recruitment capacity and is seen as advantageous in the context of eradication (Simberloff, 2003). However, a recent study concluded that functional eradication, the reduction of introduced species density below levels that cause unacceptable effects on the native community, of *U. cinerea* may not be a viable management strategy (Cheng et al., 2021). Following removal of 30,000 *U. cinerea* in its introduced range in San Francisco Bay by over 300 volunteers, abundances were reduced but not to target densities. Consequently, impacts on oysters were not reduced (Cheng et al., 2021). Further, historically, oyster growers have attempted to control *U. cinerea* by manually removing adults and egg capsules, but even local eradication proved difficult, and in some cases, growers abandoned oyster beds due to the intense predation (Cohen, 2005). Faasse (2009) reported that the population of *U. cinerea* at Gorishoek, The Netherlands, has been steadily growing despite regular collections by hand. Broadly, mechanical, manual and chemical removal (e.g. using formalin, potassium permanganate, chlorol (10% chlorine), phenol (0.15% in seawater) and copper sulphate) and freshwater treatment has been documented as ineffective or too environmentally costly (Locke & Hanson, 2009). Possible reasons for failed eradication may include: the tendency of the species to burrow into sediment and enter a low-activity state of quasi-hibernation over winter (Carriker, 1955) providing spatial and temporal refuge; and the "hydra effect" where populations increase in density in response to a reduction in negative intraspecific interactions (competition, cannibalism) following removals (Abrams, 2009; de Roos et al., 2007).

			Generally, eradication is more effective for populations of lower abundance and persistence, in the early stages of invasion (Simberloff et al., 2013). An understanding of the abundance and persistence of the target *U. cinerea* population in the risk assessment area would be necessary in order to evaluate the likely success of eradication.
1.28. Estimate the overall likelihood of establishment (mention any key issues in the comment box).	very likely	very high	This species has already established in multiple locations outside its native range, including within the risk assessment area. This suggests that conditions present in the risk assessment area are suitable and further establishment of this species, assuming its successful introduction, will be very likely.

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	**Larval dispersal:** *U. cinerea* does not have a pelagic larval phase, limiting its spread by natural means. **Adult dispersal**: Further, adult *U. cinerea* appear to have limited mobility with results from a pilot mark-recapture study of over 500 individuals, highlighting that *U. cinerea* moved a maximum of 4m from their origin over the course of eight months (A.L. Chang, unpublished data, from Cheng et al., 2021).
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	high	Transfer of this species as a contaminant on translocated shellfish is likely to be the key mechanism of spread of this species in the risk assessment area. 20% of total records of *U. cinerea* in GB are from before 1940, and 84% prior to 1950 (NBN Atlas UK). Domestic farm to farm movements of oysters are known to occur within GB but are relatively infrequent (Fish Health Inspectorate for England and Wales 2023, personal communication). However, it is challenging to comment on the speed of spread of the organism given the often large time lags between the introduction of a species and its recording/ reporting, and due to the absence of population genetic evidence to confirm that the origin of a new population was within or outwith GB.
2.3. Within the risk assessment area, how difficult would it be to contain the organism?	difficult	medium	Containment of invasive species in open systems such as the marine environment is very difficult. However, its limited mobility, association with oysters and other sessile molluscs, and preference for intertidal habitat does provide some advantage for *U. cinerea* containment over other marine species. Banning transfer of shellfish from areas where the species occurs is likely the only way to contain *U. cinerea*. Such an approach a has been implemented in America

			and The Netherlands to control *Ocinebrellus inornatus* (Japanese oyster drill) (National Research Council, 2004; Fey-Hofstede et al., 2010; Didderen &Gittenberger 2013). Legislation would be required to ensure such a ban was adhered to, especially in light of the potential economic losses which would be incurred by shellfish farmers as a result of movement bans.
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.	see comment	medium	Estuaries and bays, shellfish farms and wild oyster and mussel beds in close proximity.
2.5. What proportion (%) of the area/habitat suitable for establishment (i.e. those parts of the risk assessment area where the species could establish), if any, has already been colonised by the organism?	0-10	low	Occurrences of the species within the risk assessment area are reasonably isolated geographically (figure 1), in particular outside the initial introduction area of Essex and Kent. However, limited marine monitoring to inform the presence and abundance of this species, in addition to lags in reporting and data flow means confidence is low. High abundance in 1950s following identification of *U. cinerea* in 1928 was noted, but the introduction of tributyl tin (TBT) antifouling biocides (now banned) and associated pollution, coupled with crashes in oyster populations reduced the abundance of *U. cinerea* drastically (Fey et al., 2010 and references therein), likely markedly limiting its spread.
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	low	Monitoring of this species presence and abundance is lacking in the risk assessment area. However, evidence suggests a lag of ~20 years (see section 2.5) between initial introduction and high abundance and impact in the risk assessment area. Further, since its initial introduction, there have been only a few, reports of the species in new locations (though these may originate from separate introduction events rather than spread).
2.7. What other timeframe (in years) would be appropriate to estimate any significant further spread of the organism in the risk assessment	80	low	In the absence of marine monitoring with adequate spatial and temporal coverage evidence to underpin answer to the question is lacking. However, historic information suggests that spread may be slow.

area? (Please comment on why this timeframe is chosen.)			
2.8. In this timeframe what proportion (%) of the endangered area/habitat (including any currently occupied areas/habitats) is likely to have been invaded by this organism?	0-10	low	As above, in the absence of marine monitoring with adequate spatial and temporal coverage evidence to underpin answer to the question is lacking. However, the slow spread and absence of evidence for endangered areas and habitats being invaded suggests *U. cinerea* is likely to invade only a small proportion of the endangered area/habitat.
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	low	Natural spread is limited. While increased localised abundance following introduction has been documented, spread throughout the risk assessment area via the movement of aquaculture stock seems to have been slow to moderate.

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?	moderate	low	*U. cinerea* is known to cause serious declines in populations of molluscs, including those of commercial importance, causing up to 50-70% population loss (Carriker, 1955; Fey et al., 2010; Hancock, 1954 and references therein), though such impacts are dependent on density (Faasse, 2009) which has been recorded to range from 2-947/m^2 (Carriker, 1955). Though costs of *U. cinerea* within its existing range have not been quantified, damage inflicted by *U. cinerea* and *Eupleura caudata* combined was estimated to be in the region of millions of dollars per year in the USA alone (Manzi, 1970).
2.11. How great is the economic cost of the organism **currently** in the risk assessment area **excluding management** costs (include any past costs in your response)?	minor	moderate	Costs associated with the species currently in the risk assessment area have not been quantified. However, given the current limited distribution and low abundance (though note the lack of monitoring to evidence this), and the absence of reports of significant oyster losses due to *U. cinerea*, costs are estimated to be minor.
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?	moderate	low	Costs associated with the species have not been quantified and thus future costs are unknown. However, economic losses may be incurred through loss of commercial shellfish stocks. It has been estimated that a single oyster drill can consume about 40 oyster spat per year (Cohen, 2005; Eno, 1996). During its lifetime (> six years) a single individual is capable of consuming 240

			young oysters (Fey et al., 2010). The consumption of the mussel *Mytilus edulis* by *U. cinerea* has been shown to vary with temperature. It has also been reported that at temperatures ranging between 15-20 °C, a single *U. cinerea* consumed 0.5-1 mussel per week (Fey et al., 2010 and references therein). Oyster spat loss of up to 75% have been documented for Essex (Cole, 1942; Hancock, 1954) Using 2011/12 market prices, the value of the UK Pacific oyster industry was estimated at £13 million (Annual Gross Output, being 5 times the first sale value), and over £10 million Gross Value Added (GVA) for total UK production (Syvret et al., 2021). Assuming large scale spread (a very worse-case scenario) and based on the commercial value of Pacific oysters alone the impact of *U. cinerea* could be on the scale of £Ms. Further costs may occur as a result of loss of other commercial species but also indirectly, for example through loss of ecosystem services and failure of native oyster restoration projects. However, costs on such a scale have not been realised thus far.
2.13. How great are the economic costs **associated with managing** this organism **currently** in the risk assessment area (include any past costs in your response)?	minimal	low	Specific management of *U. cinerea* is not known to be taking place currently in the risk assessment area.
2.14. How great are the economic costs **associated with managing** this organism likely to be **in the future** in the risk assessment area?	moderate	low	As highlighted above (see section 1.21), eradication is unlikely to be feasible for this species and therefore unlikely to be attempted unless evidence of efficacy comes to light. Therefore, management is likely to primarily target containment and prevention of spread through shellfish stock movement biosecurity measures. Increased monitoring and biosecurity may incur increased staff costs as a result of more time-intensive processes. Shellfish industry costs (in addition to yield loss) may also be incurred if movement restrictions are put in place as part of management strategy (though legislation will be required to underpin such management).

2.15. How important is environmental harm caused by the organism within its existing geographic range **excluding the risk assessment area**?	moderate	low	The impact of *U. cinerea* on the environment has not been studied (Faasse, 2009). However, one could hypothesise that the loss of filter feeding molluscs such as oysters, as a result of *U. cinerea* predation, may result in poorer water quality.
2.16. How important is the impact of the organism on biodiversity (e.g. decline in native species, changes in native species communities, hybridisation) **currently** in the risk assessment area (include any past impact in your response)?	minor	medium	Biodiversity impacts associated with the species currently in the risk assessment area have not been assessed. However, given the current limited distribution and low abundance (though note the lack of monitoring to evidence this), and the absence of reports of significant loss of oyster and other affected species due to *U. cinerea*, biodiversity impacts are likely to be low at the present time. However, historic impact on oyster reefs which have biodiversity benefits, including feeding grounds for some bird species (Herbert et al., 2018), has been considerable (Hancock, 1954).
2.17. How important is the impact of the organism on biodiversity likely to be in the **future** in the risk assessment area?	moderate	low	*U. cinerea* can have a competitive advantage over native species (e.g. missing parasites, (Torchin et al., 2003)), causing serious declines in prey populations and affecting the structure of communities at local scales. Impact on biodiversity will depend on the geographic spread and abundance of *U. cinerea* but at a local level, impact could be moderate.
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)?	minor	low	While research into impacts of *U. cinerea* on ecosystem function is not known, its impact through predation will potentially cause diverse knock-on impact, including negative impacts on habitats (e.g. oyster reefs). Low abundance currently suggests minimal current impact but historic impact has been substantial at local scales.
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	moderate	low	Through predation on mollusc species, including oysters, *U. cinerea* is known to impact ecosystem functioning.

organism likely to be in the risk assessment area in the **future**?			
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?	minor	low	There is no known evidence to support the conclusion around current impact of *U. cinerea* on species of conservation importance, or on Marine Protected Areas (MPAs) in the risk assessment area. At a broader geographical scale, *U. cinerea* has not been reported in marine reserves, or documented to threaten endangered species (Faasse, 2009).
2.21. How important is decline in conservation status (e.g. sites of nature conservation value, WFD classification) caused by the organism likely to be in the **future** in the risk assessment area?	moderate	low	The impact of *U. cinerea* on oysters may threaten the success of native oyster restoration work being undertaken in the risk assessment area. Further, Blue mussel beds and native oyster reefs are designated features of MPAs such that the impact of *U. cinerea* on these could affect the condition of MPAs and achievement of relevant conservation targets.
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	medium	Hybridisation is not documented.
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	low	Social and human health impacts are not known.
2.24. How important is the impact of the organism as food, a host, a symbiont or a vector for other damaging organisms (e.g. diseases)?	minimal	low	There is some evidence to suggest that the species is parasitized by the digenean trematode flatworm *Parorchis avitus* described from the herring gull, *Larus argentatus*. Its larvae *Cercaria sensifera* live in the snails *U.*

			cinerea and *Nucella lapillus.* The parasite is found in the reproductive and digestive glands of *U. cinerea* (Carriker, 1955; Cole, 1942).
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)	minimal	low	Positive impacts could result from predation of *U. cinerea* on other pest species such as *C. gigas*.
2.26. How important are the expected impacts of the organism despite any natural control by other organisms, such as predators, parasites or pathogens that may already be present in the risk assessment area?	moderate	medium	Scoring aligns with impact scores above given limited means by which the species can be controlled.
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).	Shellfish production sites, oyster and mussel reefs.	high	Along the south coast of England in particular there are many oyster cultivation sites as well as several dense aggregations of wild oyster reefs (Wood et al., 2021). These provide ideal habitat for *U. cinerea* with environmental conditions suitable for establishment. Farmed oysters, and to a lesser extent mussels, may be predated on by the species causing reduced yields and economic losses.
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	Ecological and economic impacts associated with *U. cinerea* are tightly linked to its predation on oysters.

RISK SUMMARIES			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	very likely	very high	*U. cinerea* has already entered the risk assessment area. It is associated with only a single (human mediated, accidental) pathway and this pathway remains active in the risk assessment area.
Summarise Establishment	very likely	very high	*U. cinerea* is already established in the risk assessment area. The species has many traits associated with high likelihood of establishment including high adaptability to different environments, wide range of food/prey species, long lived and high reproductive potential.
Summarise Spread	slowly	low	*U. cinerea* does not have a pelagic larval phase and *U. cinerea* adults have limited mobility limiting spread by natural means.
Summarise Impact	moderate	medium	Serious declines of prey, including those of commercial value will result in potentially moderate impact both ecologically and economically. In particular, *U. cinerea* causes declines in the population size of at least 1 native taxon. However, no evidence of extinction of a native taxon exists and impacts are likely to be highly localised. The impact of *U. cinerea* on oysters may also threaten the success of native oyster restoration work being undertaken in the risk assessment area.
Conclusion of the risk assessment	medium	medium	Eradication of *U. cinerea* is not feasible and oyster restoration is known to fail in the presence of *U. cinerea*. Entry and establishment is very likely, and though spread is unlikely to be rapid and the single pathway can be managed, local abundance may increase rapidly, and local impacts may be significant, based on historic evidence.

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?	Temperature Ocean acidification	high	*U. cinerea* life history shows temperature dependence and there is evidence to suggest that the species' shell may be impacted by ocean pH (see section 3.3, and sections referenced therein, for further detail)
3.2. What is the likely timeframe for such changes?	50 years	medium	
3.3. What aspects of the risk assessment are most likely to change as a result of climate change?	Establishment Impact	low	Though exhibiting high environmental tolerance *U. cinerea* shows temperature dependant reproduction, development and feeding (see section 1.15). These will be impacted by climate change. For example, increased temperatures associated with climate change are likely to result in earlier spawning and spawning over longer durations, potentially leading to increases in population size under climate change conditions. Extreme temperature changes will also impact survival, though widely divergent responses to warming have been reported in individuals from different geographic regions, indicating the role of acclimation in thermal tolerance (Villeneuve et al., 2021). Similar temperature dependencies occur in prey species, with, for example, increased persistence and abundance of pacific oysters reported under climate change scenarios (Teixeira Alves et al., 2021). Further, a study looking into climate change impacts showed a 60% increase in feeding rate in *U. cinerea* subject to a warmer treatment (temperature increased by 4°C above ambient), indicating potential exacerbation of *U. cinerea* impacts under climate change (Lord & Whitlatch, 2013)

			In addition, sea level rise associated with climate change may result in estuaries being flooded with salt water. The tolerance of *U. cinerea* to increased salinity will be advantageous and may result in an increase in population size and therefore an increase in impacts. Climate change may also have detrimental effects on *U. cinerea*. In particular, heavy erosion of *U. cinerea* shells was seen under ocean acidification conditions (Lord et al., 2019)
ADDITIONAL QUESTIONS - RESEARCH			
4.1. If there is any research that would significantly strengthen confidence in the risk assessment please summarise this here.	Impacts. Distribution and abundance.		Further research around ecological and environmental impacts would allow more confidence in the assessment of impact. Monitoring to facilitate baseline understanding of the distribution and abundance of the species will inform risk assessment, in particular questions around spread and future impact. Cost implications of *U. cinerea* invasion are largely unclear – further research into costs relating to management and economic impacts are also recommended. Consideration of the implications of climate change on impacts and distribution and abundance would also be valuable.

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