Risk Assessment of *Corbicula fluminea*

Name of Organism:	*Corbicula fluminea* (Müller 1774) - Asian Clam
Objective:	Assess the risks associated with this species in Ireland
Version:	Final 15/09/2014
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Expert reviewer	Jaimie Dick

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About the risk assessment

This risk assessment is based on the **N**on-native species **AP**plication based **R**isk **A**nalysis (NAPRA) tool (version 2.66). NAPRA is a computer based tool for undertaking risk assessment of any non-native species. It was developed by the European and Mediterranean Plant Protection Organisation (EPPO) and adapted for Ireland and Northern Ireland by Invasive Species Ireland. It is based on the Computer Aided Pest Risk Analysis (CAPRA) software package which is a similar tool used by EPPO for risk assessment.

Notes: Confidence is rated as low, medium, high or very high.
Likelihood is rated as very unlikely, unlikely, moderately likely, likely or very likely.
The percentage categories are 0% - 10%, 11% - 33%, 34% - 67%, 68% - 90% or 91% - 100%.
N/A = not applicable.

This is a joint project by Inland Fisheries Ireland and the National Biodiversity Data Centre to inform risk assessments of non-native species for the European Communities (Birds and Natural Habitats) Regulations 2011. It is supported by the National Parks and Wildlife Service.

DOCUMENT CONTROL SHEET

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Version Control Table

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Final	Complete	Dr Michael Millane	Dr Joe Caffrey	Dr Cathal Gallagher	15/09/2014

Stage 1 - Organism Information *The aim of this section is to gather basic information about the organism.*			
N	**QUESTION**	**RESPONSE**	**COMMENT**
1	What is the reason for performing the risk assessment?		A risk assessment is required as this species is listed as a "Non-native species subject to restrictions under Regulations 49 and 50" in the Third Schedule of the European Communities (Birds and Natural Habitats) Regulations 2011, SI 477/2011.
2	Identify the organism. Is it clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?	YES	*Corbicula fluminea* (Müller 1774), *Corbicula fluminalis* *(Müller 1774), *Corbicula leana* (Prime, 1864), *Corbicula manilensis* (Philippi 1844); Asian Clam, Asiatic Clam, Clam, Asian, Prosperity Clam (CABI 2012), Golden Clam and Good Luck Clam (Foster 2014). * Although *Corbicula fluminalis* is used as a synonym for *Corbicula fluminea*, the two have recently been confirmed as separate species after some previous taxonomic confusion due to ecomorphotypic variation (reviewed in CABI 2012). Indeed, Roy *et al*. (2014), consider *C fluminalis* as a separate and potentially new invader in British Isles.
3	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	
4	Describe the organism.		*Corbicula fluminea* "is a small clam with an inflated shell, slightly round to triangular in shape. The most distinctive feature is the shell which bears numerous heavy concentric ridges. The shell is usually pale brownish or yellowish brown, olivaceous to black. Internally there are three cardinal teeth in each valve and the lateral teeth are heavily serrated. The nacre (i.e. inner shell layer) varies from white to salmon or deep purple." "The life span is about one to seven years, and it can grow to a shell length of 50-65 mm, although it is usually less than 25 mm." (excerpt from CABI 2012).
5	Does a relevant earlier risk assessment exist? (give details of any previous risk assessment)	YES	A preliminary, prioritisation risk assessment was previously carried out in Ireland as part of the Risk Analysis and Prioritisation for Invasive and Non-native Species in Ireland and Northern Ireland (Kelly *et al*. 2013). This assessment designed *Corbicula fluminea* as a 'high risk' invasive species.
6	If there is an earlier risk assessment is it still entirely valid, or only partly valid?	PARTIAL	Only a preliminary risk assessment was previously conducted in Ireland (refer to Question 5). This is considered 'partially valid' as being a prioritisation exercise, only a final score of invasiveness was given in the report.
7	Where is the organism native?		China, Japan, Philippines, Republic of Korea, eastern Russia, Taiwan and Thailand (Karatayev *et al*. 2007; CABI 2012); and possibly parts of Africa and Australia (Sousa *et al*. 2008), although the literature is scant in this regard.

Stage 1 - Organism Information *The aim of this section is to gather basic information about the organism.*			
N	**QUESTION**	**RESPONSE**	**COMMENT**
8	What is the current global distribution of the organism (excluding Ireland)?		Asia (China, Japan, Republic of Korea, Philippines, eastern Russia, Taiwan and Thailand); Australia; Central America (Panama); Europe (Belgium, Britain, Czech Republic, Germany, Hungary [Cupsa 2014]; Portugal, Republic of Moldova [Munjiu and Shubernetski 2011], Romania [Cupsa 2014], Russia, Serbia [Paunović 2007]; Spain and The Netherlands); North America (Canada, Mexico and USA); and South America (Argentina, Brazil, Uruguay and Venezuela) (reviewed in CABI 2012 unless other reference in square brackets provided). The authors could find no specific references in the literature that confirms the current presence of *Corbicula fluminea* in Africa.
9	What is the current distribution of the organism in Ireland?		*Corbicula fluminea* was first recorded in Ireland in the freshwater tidal section of the lower River Barrow at St. Mullin's in April 2010 (Sweeney 2009). Follow up studies confirmed its presence downstream of this location towards New Ross, and directly upstream of the weir at St. Mullin's above the tidal limit (CAISIE 2013) and in the adjoining the River Nore upstream to its tidal limit at Inistioge (Caffrey *et al*. 2011; CAISIE 2013). *Corbicula fluminea* was subsequently recorded in the River Shannon at Carrick-on-Shannon (in August 2010, Hayden and Caffrey 2013), Lough Derg in January 2011 (Minchin pers. comm.) and two other locations on the River Shannon, subsequent to this (Lanesborough [Sheehan *et al*. 2013] and Banagher to Portumna [Minchin 2014]). Two clam shells were also found in the Grand Canal, 20 km from its connection to the River Shannon (Minchin 2014). The 120 km long Grand Canal traverses the Irish midlands, interconnecting the River Shannon and River Barrow systems. Based on its invasion history elsewhere in the world (Karatayev *et al*. 2007; Sousa *et al*. 2008), it is highly likely that further spread to new locations in Ireland has occurred since that time (Minchin 2014).
10	Is the organism known to be invasive anywhere in the world?	YES	*Corbicula fluminea* is known to be invasive in all areas where present outside its native range (CABI 2012).

Stage 2 - Detailed assessment: Section A - Entry

This section evaluates the probability of entry of an organism into Ireland. For organisms which are already present, only complete the entry section for currently active pathways of entry and potential future pathways. The entry section need not be completed for pathways which have allowed an organism to enter in the past but are no longer active.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.01	How many active/future pathways are relevant to the potential entry of this organism (n/a, very few, few, moderate number, many or very many)?	MANY	VERY HIGH	Ballast water; boating, angling and other water-based activities; food; contaminant of the trade in aquatic animal or plants.
1.02	List significant pathways through which the organism could enter. Where possible give detail about the specific origins and end points of the pathways.	1. Ballast water 2. Boating, angling and other water-based activities 3. Food 4. Aquarium trade and fish stocking		Ballast water from International shipping can act as a vector to transfer *Corbicula fluminea* from an infested area abroad to Ireland (reviewed in CABI 2012). The risk of introduction in association with boating, angling and other water-based activities arises from any travel to Ireland from an infested area abroad where equipment is inadvertently contaminated with juvenile or adult *Corbicula fluminea*. This is considered to be the principal anthropogenic-mediated pathway responsible for the spread of the species from existing areas within Ireland (Lucy *et al*. 2012). Natural dispersal and other internal spread pathways are considered later in this risk assessment document (refer to Question 2.11, 3.02, and 3.03). *Corbicula fluminea* may be deliberately introduced to Ireland or transferred from one water to another as a food source. It is extensively cultivated for food in parts of Asia such as Japan and Taiwan (reviewed in CABI 2012). The introduction of the species to North America is believed to have occurred *via* this pathway (Counts 1986). *Corbicula fluminea* has the potential to be imported for use as an ornamental species in aquaria or enter Ireland as a contaminant of the trade in aquatic animals and plants for aquaria, and in association with fish stocking for angling.

Pathway 1 – Ballast water				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
1.03	Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (e.g. the organism is a contaminant of imported goods)?	ACCIDENTAL	VERY HIGH	Ballast water is believed to have been responsible for the inadvertent introduction of numerous non-native species worldwide (Minchin and Eno 2002; Gollasch 2006), including the *Corbicula fluminea* (reviewed in viewed in Karatayev *et al*. 2007).
1.04	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?	UNLIKELY	LOW	No information is available on whether large numbers of *Corbicula fluminea* travel along this pathway to Ireland. The risk of transfer to Ireland from other Northern Hemisphere ports is likely to be heightened when ballast water is taken on during the spawning season (*c*. May to October) when water temperatures suitable for reproduction (≥ 15^{o}C) are attained (McMahon 1999; Rajagopal *et al*. 2000).
1.05	How likely is the organism to enter Ireland undetected or without the knowledge of relevant competent authorities?	VERY LIKELY	VERY HIGH	Awareness by the relevant competent authorities at points of entry to recognise and identify *Corbicula fluminea* is limited or non-existent at present. In any case, the detection of juvenile stages of the clam can be difficult because of their small size.
1.06	How likely is the organism to survive during passage along the pathway?	LIKELY	LOW	Survival along this pathway is ultimately dependent on a number of factors including duration and conditions of transport, and the suitability of environmental conditions where the species is introduced. An overview in his regard is given by Smith *et al*. (1999), "A successful ballast-mediated invasion is a multi-stage process. It is one that requires intake of potential invaders along with ballast water into the ship, survival of species during the voyage, colonization of the new environment, and continued reproduction of the introduced species (Carlton 1985). At present we have few quantitative data to evaluate which factors are critical to success across each stage. For example, the likelihood of invasion may be influenced by the amount of ballast water released, the diversity and abundance of organisms in the ballast water, and the degree of similarity in abiotic and biotic conditions in the donor and receiving regions (Carlton 1996)".

Pathway 1 – Ballast water				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
1.07	How likely is the organism to arrive during the months of the year appropriate for establishment?	LIKELY	LOW	Ballast water dumping from international shipping is not seasonally restricted and may occur throughout the year. The *International Convention for the Control and Management of Ships' Ballast Water and Sediments* (IMO 2004) has set out best practice measures to minimise the risk of invasive species introductions (e.g. mid-ocean ballast water exchange). Ireland is a signatory to this international legally binding agreement but has not yet enacted it. However, Northern Ireland (under the UK) is not. One notable area of origin where *Corbicula fluminea* is present is in the vicinity of Rotterdam in the Rhine-Meuse Delta in The Netherlands (Bij de Vaate 1991). Rotterdam is the major European port for international shipping and is Ireland's main transhipment and intercontinental hub for deep-sea cargo (IMDO 2009). The Ireland – Rotterdam short-sea shipping routes are the busiest of all routes out of Ireland accounting for 36% of lo/lo (i.e. lift-on, lift-off) sailings. As of 2009, there were five operators providing 19 weekly sailings between the two countries from Dublin, Cork and Waterford (and Belfast in Northern Ireland), and previously from Drogheda and Foynes (IMDO 2009).
1.08	How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	MODERATELY LIKELY	MEDIUM	Refer to response to Question 1.06 for factors that will determine a successful ballast water transfer. There is an abundance of suitable habitat available in Ireland for *Corbicula fluminea* (Lucy *et al*. 2012). The species can live in both freshwaters and brackish waters (to an upper salinity limit of 14 -17 psu). It can inhabit rivers, lakes, reservoirs, canals, streams and estuaries with silt, mud, sand or gravel substrates (McMahon 1999; reviewed Global Invasive Species Database 2005). The species has a preference for lotic conditions and is generally intolerant of pollution (reviewed Global Invasive Species Database 2005). The majority of freshwaters in Ireland are considered suitable for establishment with the exception of a small number of headwater rivers and lakes located in non-limestone areas, which are naturally acidic and poorly-buffered with a pH <5.6 and oligotrophic (in the case of lakes) (Lucy *et al*. 2012). Therefore, contaminated ballast water discharged into an estuary has the potential to directly transfer this species to a suitable habitat and result in further secondary spread through a variety of natural and

Pathway 1 – Ballast water				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
				anthropogenic vectors as described elsewhere in the section of the risk assessment.
1.09	Estimate the overall likelihood of entry into Ireland based on this pathway?	MODERATELY LIKELY	LOW	As described in response to Question 1.06 there are number of factors that will determine a successful ballast water transfer. There is no information to assess whether ballast water from ships coming to Ireland contains *Corbicula fluminea*. There is also no information available on how much ballast water is discharged in or around Ireland. Nevertheless, the regular movement of ships between Rotterdam and Irish ports raises some concern on the potential for further introductions to Ireland *via* this pathway.
1.10	Do other pathways need to be considered?	YES		

Pathway 2 – Boating, angling and other water-based activities				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
1.03	Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (e.g. the organism is a contaminant of imported goods)?	ACCIDENTAL or INTENTIONAL	VERY HIGH	The overland or cross-channel movement of boats, boat trailers, boat engines, angling gear and other items used in water activities from an infested to uninfested area has the potential to inadvertently introduce and spread this organism if such equipment is contaminated with viable adults or juveniles of *Corbicula fluminea* (Caffrey *et al*. 2011; Lucy *et al*. 2012; Minchin 2014). This includes the import of used boats from abroad. In addition, the discarding of unused *Corbicula fluminea* fishing bait by foreign anglers has been speculated as a potential source of introduction and spread (Minchin 2014).
1.04	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?	MODERATELY LIKELY to LIKELY	HIGH	In the absence of implementing appropriate biosecurity measures, there is an increased potential for the inadvertent spread of viable specimens overland from infested to uninfested waters. It is moderately likely that 'large numbers' of *Corbicula fluminea* will travel along this pathway over the course of one year. This risk increases during the spawning season

Pathway 2 – Boating, angling and other water-based activities				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
				(*c.* May to October) when water temperatures suitable for reproduction (≥ 15°C) are attained (McMahon 1999; Rajagopal *et al*. 2000). At this time, juveniles may be present in the water column. These have 'sticky' byssal threads which can attach to equipment such as boat hulls or contaminate substrates, which may be inadvertently carried with the equipment (McMahon 1999; Caffrey *et al*. 2011).
1.05	How likely is the organism to enter Ireland undetected or without the knowledge of relevant competent authorities?	VERY LIKELY	VERY HIGH	Awareness by the relevant competent authorities at points of entry to recognise and identify *Corbicula fluminea* is limited or non-existent at present. In any case, the detection of juvenile stages of the clam can be difficult because of their small size.
1.06	How likely is the organism to survive during passage along the pathway?	LIKELY	HIGH	Survival along this pathway is ultimately dependent on environmental conditions and duration of transport. *Corbicula fluminea* can survive emersion for long periods e.g. median tolerance times of up to 14.2 days at 15 °C (Byrne *et al*. 1988).
1.07	How likely is the organism to arrive during the months of the year appropriate for establishment?	LIKELY	HIGH	Boating, angling and other water activities are not necessarily restricted to a particular season and may occur throughout the year. *Corbicula fluminea* could survive an introduction to an Irish waterway at any time of year and not reproduce until conditions become favourable. Specimens in Ireland have been observed to survive water temperatures as low as 0.9°C for limited periods (almost two weeks at this water temperature under a surface ice layer in Lough Derg - Minchin 2014).
1.08	How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	LIKELY	HIGH	As noted in Pathway 1 , Question 1.08, Ireland has an abundance of freshwaters, the majority of which are suitable for the establishment of *Corbicula fluminea* (Lucy *et al*. 2012). The movement of boats, boat trailers, boat engines, angling gear and other items used in water activities can act as a direct pathway to transfer this organism from an infested water to a suitable habitat elsewhere (Caffrey *et al*. 2011; Lucy *et al*. 2012; Minchin 2014). As *Corbicula fluminea* has a high resilience to desiccation (Byrne *et al*. 1988), successful transfer would be dependent on the environmental conditions and duration of transport.
1.09	Estimate the overall likelihood of entry into Ireland based on this pathway?	LIKELY	HIGH	This pathway depends on *Corbicula fluminea* surviving a cross-channel journey in association with the movement of boats, boat trailers, boat

Pathway 2 – Boating, angling and other water-based activities				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
				engines, angling gear and other items used in water activities from an infested water abroad to an uninfested water in Ireland. Britain is the closest neighboring jurisdiction to Ireland where *Corbicula fluminea* is present. Since it was discovered there in 1998 (Baker et al. 1999 as cited in Elliot and zu Ermgassen 2008), the clam has been recorded in 17 x 10 km squares (NBN Gateway 2014) and appears to be spreading further after being initially being confined to the south-east of the country (Elliot and zu Ermgassen 2008). There are no specific data available on the movement of boats, boat trailers, boat engines, angling gear and other items used in water activities from infested areas in Britain, or indeed elsewhere, to Ireland. However, it is considered likely that the organism can enter *via* this pathway from such areas (Caffrey *et al*. 2011; Lucy *et al*. 2012; Minchin 2014). In any case, new range expansions of *Corbicula fluminea* in Ireland are more likely to come from existing populations than from populations abroad.
1.10	Do other pathways need to be considered?	YES		

Pathway 3 – Food				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
1.03	Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (e.g. the organism is a contaminant of imported goods)?	INTENTIONAL	VERY HIGH	There is no evidence that *Corbicula fluminea* has been introduced to Ireland as a food source. However, it has been suggested as one of a number of potential pathways responsible for its presence in the Barrow River (Caffrey *et al*. 2011). This population is considered most likely to be the founder population in Ireland (Caffrey *et al*. 2011; Minchin 2014). As stated previously, *Corbicula fluminea* is extensively cultivated for food in parts of Asia such as Japan and Taiwan (reviewed in CABI 2012). The introduction of the species to North America is believed to have occurred *via* this pathway (Counts 1986).

Pathway 3 – Food				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
1.04	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?	UNLIKELY	MEDIUM	It is considered unlikely that large numbers of *Corbicula fluminea* will travel along this pathway. However, this may increase in future as awareness increases of its use as a food source. However, large numbers are not necessarily required to start a new population – a single individual may be capable of doing so, as the species can self-fertilise and produce viable off-spring (JTA, Dick, personal communication).
1.05	How likely is the organism to enter Ireland undetected or without the knowledge of relevant competent authorities?	VERY LIKELY	VERY HIGH	Awareness by the relevant competent authorities at points of entry to recognise and identify this species is limited or non-existent at present.
1.06	How likely is the organism to survive during passage along the pathway?	VERY LIKELY	VERY HIGH	Survival would be highly likely as the intention would be to introduce live specimens to found a population that could be exploited as a food source.
1.07	How likely is the organism to arrive during the months of the year appropriate for establishment?	LIKELY	HIGH	*Corbicula fluminea* could survive an introduction to an Irish waterway at any time of year and not reproduce until conditions become favourable. Specimens in Ireland have been observed to survive water temperatures as low as 0.9^{o}C for limited periods (almost two weeks at this water temperature under a surface ice layer in Lough Derg - Minchin 2014).
1.08	How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	VERY LIKELY	VERY HIGH	As the majority of freshwater and brackish waters are suitable for establishment (Lucy *et al*. 2012), survival is very likely. Transfer would also be intentional, with the aim of keeping specimens alive during transit.
1.09	Estimate the overall likelihood of entry into Ireland based on this pathway?	MODERATELY LIKELY	MEDIUM	As stated previously, there is no evidence that *Corbicula fluminea* has been introduced to Ireland as a food source. However, it has been suggested as one of a number of potential pathways responsible for its presence in the Barrow River (Caffrey *et al*. 2011) which is considered most likely to be the founder population in Ireland (Caffrey *et al*. 2011; Minchin 2014).
1.10	Do other pathways need to be considered?	YES		

Pathway 4 - Aquarium trade and fish stocking				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
1.03	Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (e.g. the organism is a contaminant of imported goods)?	INTENTIONAL or ACCIDENTAL	HIGH	*Corbicula fluminea* has the potential to be sold intentionally through the aquarium trade. The species may also enter Ireland as a contaminant of the trade in aquatic animals and plants for aquaria and in association with fish stocking for angling (Minchin 2014). .
1.04	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?	UNLIKELY	MEDIUM	It is considered unlikely that *Corbicula fluminea* has been sold through the aquarium trade in Ireland to date (Minchin 2014). The authors can find no evidence in this regard. The enactment of Regulations 50 of the European Communities (Birds and Natural Habitats) Regulations 2011 (SI 477/2011) may limit any the trade in this species in Ireland in future. Therefore, it is unlikely that 'large numbers' will travel along this pathway. As stated previously, large numbers are not necessarily required to start a new population – a single individual may be capable of doing so, as the species can self-fertilise and produce viable off-spring (JTA, Dick, personal communication). It is difficult to assess the likelihood of *Corbicula fluminea* entering Ireland as a contaminant of the trade in aquatic animals and plants for aquaria and in association with fish stocking for angling as no such information is available.
1.05	How likely is the organism to enter Ireland undetected or without the knowledge of relevant competent authorities?	VERY LIKELY	VERY HIGH	Awareness by the relevant competent authorities at points of entry to recognise and identify this species is limited or non-existent at present.
1.06	How likely is the organism to survive during passage along the pathway?	VERY LIKELY	VERY HIGH	Survival is likely as the specimens would be in an aquatic environment.
1.07	How likely is the organism to arrive during the months of the year appropriate for establishment?	LIKELY	HIGH	This pathway could be active throughout the year. *Corbicula fluminea* could survive an introduction to an Irish waterway at any time of year and not reproduce until conditions become favourable.
1.08	How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	LIKELY	HIGH	Specimens could be introduced directly to the wild through an aquarium dump or in association with fish stocking transfers. As previously stated, there is an abundance of suitable habitat available in Ireland for *Corbicula fluminea* (Lucy *et al*. 2012). The species can live in both freshwaters and brackish waters (to an upper salinity limit of 14 -

Pathway 4 - Aquarium trade and fish stocking				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
				17 psu). It can inhabit rivers, lakes, reservoirs, canals, streams and estuaries with silt, mud, sand or gravel substrates (McMahon 1999; reviewed Global Invasive Species Database 2005). The species has a preference for lotic conditions and is generally intolerant of pollution (reviewed Global Invasive Species Database 2005). The majority of freshwaters in Ireland are considered suitable for establishment with the exception of a small number of headwater rivers and lakes located in non-limestone areas, which are naturally acidic and poorly-buffered with a pH <5.6 and oligotrophic (in the case of lakes) (Lucy *et al*. 2012).
1.09	Estimate the overall likelihood of entry into Ireland based on this pathway?	MODERATELY LIKELY	LOW	*Corbicula fluminea* is not known to be traded or kept as an aquarium species in Ireland to date (Minchin 2014). However, the latter may increase in future as the species becomes more well known and can be sourced directly from the wild (Minchin 2014). It is difficult to assess the likelihood of *Corbicula fluminea* entering Ireland as a contaminant of the trade in aquatic animals and plants for aquaria and in association with fish stocking for angling as no such information is available.
1.10	Do other pathways need to be considered?	NO		

Overall likelihood				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
1.11	Estimate the overall likelihood of entry into Ireland based on all pathways (comment on the key issues that lead to this conclusion).	MODERATELY LIKELY	MEDIUM	Further expansions in the range of *Corbicula fluminea* in Ireland are more likely to come from existing populations than from populations abroad. The risk of *Corbicula fluminea* introductions from abroad *via* the *boating, angling and other water-based activities* pathway may increase as the species increases its range in Britain. Geographically-isolated freshwater water systems where the estuary is located near a shipping port area may be at risk from foreign introductions of *Corbicula fluminea via* the *ballast water* pathway.

Stage 2 - Detailed assessment: Section B - Establishment

This section evaluates the probability of establishment of an organism within Ireland. For organisms which are already well established in Ireland there is no need to complete this section - move straight to the Spread section.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
2.01	Is the organism well established in Ireland (if there is any uncertainty answer 'unsure')	YES (LOCALLY ESTABLISHED)	HIGH	*Corbicula fluminea* is only locally established in Ireland. It is recorded in the lower River Barrow, lower River Nore and in parts of the main River Shannon system including Lough Derg. Refer to response to Question 9 for more details. Based on its invasion history elsewhere in the world (Karatayev *et al*. 2007; Sousa *et al*. 2008), it is highly likely that further spread to new locations in Ireland has occurred (Minchin 2014). However, at present, there are no further records to confirm this.
2.02	How likely is it that the organism will be able to establish in Ireland based on the similarity between local climatic conditions and the organism's current global distribution?	VERY LIKELY	VERY HIGH	*Corbicula fluminea* has already clearly demonstrated that it can establish under Irish climatic conditions.
2.03	How likely is it that the organism will be able to establish in Ireland based on the similarity between other local abiotic conditions and the organism's current global distribution?	VERY LIKELY	VERY HIGH	*Corbicula fluminea* has already clearly demonstrated that it can establish under the abiotic conditions present in Ireland. The only prohibitive abiotic conditions are considered to be non-limestone areas, which are naturally acidic and poorly-buffered with a pH <5.6, oligotrophic lakes, polluted waters and brackish waters with an upper salinity limit ≥ 14- 17 psu (Lucy *et al*. 2012).
2.04	How likely is the organism to encounter habitats necessary for the survival, development and multiplication of the organism in Ireland?	VERY LIKELY	VERY HIGH	There is an abundance of suitable habitat available in Ireland for *Corbicula fluminea* (Lucy *et al*. 2012). The species can live in both freshwaters and brackish waters (to an upper salinity limit of 14 -17 psu). It can inhabit rivers, lakes, reservoirs, canals, streams and estuaries with silt, mud, sand or gravel substrates (McMahon 1999; reviewed Global Invasive Species Database 2005). The species has a preference for lotic conditions and is generally intolerant of pollution (reviewed Global Invasive Species Database 2005). The majority of freshwaters in Ireland are considered suitable for establishment with the exception of a small number of headwater rivers and lakes located in non-limestone areas, which are naturally acidic and poorly-buffered with a pH <5.6 and oligotrophic (in the case of lakes) (Lucy *et al*. 2012).
2.05	How likely is it that establishment will occur despite competition from existing species in Ireland?	VERY LIKELY	HIGH	There is no evidence to date that competition from any existing Irish species has prevented the establishment or will prevent the establishment of *Corbicula fluminea*.

Stage 2 - Detailed assessment: Section B - Establishment

This section evaluates the probability of establishment of an organism within Ireland. For organisms which are already well established in Ireland there is no need to complete this section - move straight to the Spread section.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
2.06	How likely is it that establishment will occur despite predators, parasites or pathogens already present in Ireland?	VERY LIKELY	HIGH	The only known predator present in Ireland which has been recorded elsewhere as preying on *Corbicula fluminea* is the Common Carp (McMahon 1983 as cited in CABI 2012). Carp are considered to be very unlikely to prevent establishment in the majority of Irish waters, possibly with the exception of small ponds. In any case, Carp are only locally distributed in Ireland, being mostly confined to private pond fisheries.
2.07	How likely is it that establishment will occur despite existing management practices?	LIKELY	MEDIUM	In general, the public management of waterways is increasingly undertaken cognisant of ensuring biosecurity measures are in place to mitigate for the spread of aquatic invasive species. An increase in awareness of the threat from aquatic invasive species by some private entities has also somewhat reduced this risk. However, the inconspicuous character of the juvenile stages of *Corbicula fluminea* makes it challenging to limit its eventual spread and subsequent establishment without strict adherence by all stakeholders to biosecurity protocols.
2.08	How likely is it that management practices in Ireland will facilitate the establishment of the organism?	MODERATELY LIKELY	HIGH	Refer to Question 2.07.
2.09	How likely is it that the biological characteristics of the organism would allow it to survive eradication campaigns in Ireland?	VERY LIKELY	VERY HIGH	Once the species becomes established in a waterbody, eradication is not feasible. A high reproductive capacity (including the ability to self-fertilise), high dispersal ability and the ability to rapidly form abundant populations are biological characteristics that enable *Corbicula fluminea* to successfully resist any eradication efforts (reviewed in Caffrey *et al*.; 2011 and Lucy *et al*. 2012). Juvenile clams are often inconspicuous due to their small size and similarity to the substrate they reside in, which makes them hard to detect and target for control (authors, personal observations). The species can form abundant populations in Irish rivers, where eradication attempts can be hampered due to the flow regime (CAISIE 2013). There may be a lag phase of a number of years between the introduction of the species to a water and its detection (Caffrey *et al*. 2011). By the time it is detected, *Corbicula fluminea* can already have established abundant populations over a wide area.

Stage 2 - Detailed assessment: Section B - Establishment

This section evaluates the probability of establishment of an organism within Ireland. For organisms which are already well established in Ireland there is no need to complete this section - move straight to the Spread section.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
2.10	How likely is it that the biological characteristics of the organism will facilitate its establishment?	VERY LIKELY	VERY HIGH	*Corbicula fluminea* can colonise a wide variety of aquatic habitats types under a range of abiotic conditions. The species has a high reproductive capacity (including the ability to self-fertilise and early sexual maturity), high natural dispersal ability and rapid growth rate. These are key biological characteristics that facilitate the establishment of *Corbicula fluminea* (reviewed in Sousa *et al*. 2008; Caffrey et al. 2011 and Lucy *et al*. 2012). The species is also highly resistant to desiccation (Byrne *et al*. 1988), which can facilitate its overland spread in association with man.
2.11	How likely is it that the organism's capacity to spread will facilitate its establishment?	VERY LIKELY	VERY HIGH	*Corbicula fluminea* has a high capacity to spread by both natural and anthropogenic means (reviewed in CABI 2012). Once the species is introduced into a waterway, natural spread can occur passively downstream with the water currents, and also upstream, although much more slowly (reviewed in Lucy *et al*. 2012). The clams are able to move locally by pedal locomotion. Pediveliger larvae or small juveniles (< 2mm), released by the adults, can remain suspended in the water column and be transported long distances on water currents in prior to settlement. The sticky byssal thread formed by juvenile clams can aid this by acting as a dragline (reviewed in Lucy *et al*. 2012, Barbour *et al.* 2013 and Minchin 2014). Byssal threads also allow pediveliger and juvenile *Corbicula fluminea* to spread by attachment to equipment used in water such as boats, trailers, engines or angling gear (reviewed in Lucy *et al*. 2012, Barbour *et al.* 2013 and Minchin 2014). As *Corbicula fluminea* is a hermaphrodite and can self-fertilise, a single clam has the potential to start a new population after it spreads away from the parent population (Sousa *et al*. 2008). This further enhances its capacity for successful establishment after spread.

Stage 2 - Detailed assessment: Section B - Establishment

This section evaluates the probability of establishment of an organism within Ireland. For organisms which are already well established in Ireland there is no need to complete this section - move straight to the Spread section.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
2.12	How likely is it that the organism's adaptability will facilitate its establishment?	VERY LIKELY	VERY HIGH	*Corbicula fluminea* has a wide ecological tolerance which allows it to establish populations in many fresh and brackish water environments in Ireland. The species can live in both freshwaters and brackish waters (to an upper salinity limit of 14 -17 psu). It can inhabit rivers, lakes, reservoirs, canals, streams and estuaries with silt, mud, sand or gravel substrates (McMahon 1999; reviewed Global Invasive Species Database 2005). The species has a preference for lotic conditions and is generally intolerant of pollution (reviewed Global Invasive Species Database 2005). The majority of freshwaters in Ireland are considered suitable for establishment with the exception of a small number of headwater rivers and lakes located in non-limestone areas, which are naturally acidic and poorly-buffered with a pH <5.6 and oligotrophic (in the case of lakes) (Lucy *et al*. 2012).
2.13	How likely is it that the organism could establish despite low genetic diversity in the founder population?	VERY LIKELY	VERY HIGH	*Corbicula fluminea* is a hermaphroditic species that reproduces by androgenesis. This means that there is only a paternal lineage i.e. only male genetic material is carried on to the next generation (Pigneur *et al*. 2011; Pigneur *et al*. 2012). Despite this apparent low genetic diversity in the founder population, there has been no evidence that it has affected the establishment of Irish populations or indeed elsewhere in its introduced range in the world (e.g. Schmidlin *et al*. 2011).
2.14	Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Ireland? If possible, specify the instances of invasion elsewhere in the justification box	VERY LIKELY	VERY HIGH	*Corbicula fluminea* has already demonstrated this capacity in Ireland.
2.15	If the organism does not establish, then how likely is it that transient populations will continue to occur?	VERY UNLIKELY	HIGH	Transient populations of *Corbicula fluminea* are very unlikely to occur. There is some potential for occasional mass population die-off events in the deeper part of lakes where a hypoxic hypolimnion can occasionally develop during warm, calm weather in the summer (Lucy *et a*l. 2012; Minchin 2014). Local die-off may occur due to pollution events as *Corbicula fluminea* is considered to be intolerant of hypoxic conditions that can occur during such events (Boltovskoy *et al*. 1997).

Stage 2 - Detailed assessment: Section B - Establishment

This section evaluates the probability of establishment of an organism within Ireland. For organisms which are already well established in Ireland there is no need to complete this section - move straight to the Spread section.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
2.16	Estimate the overall likelihood of establishment. Mention any key issues in the comments box	VERY LIKELY	VERY HIGH	*Corbicula fluminea* is already firmly established in parts of Ireland (River Barrow, River Nore and River Shannon). It is likely to continue its spread and eventually establish in the majority of suitable freshwaters and brackish waters in the country in the coming decades.

Stage 2 - Detailed assessment: Section C - Spread

This section evaluates the probability of spread of an organism within Ireland. Spread is defined as the expansion of the geographical distribution of an organism within the risk assessment area.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
3.01	What area (given in % or 10km squares) in Ireland could the organism establish (0% - 10%, 11% - 33%, 34% - 67%, 68% - 90% or 91% - 100%)?	68% - 90% of 10 km squares	HIGH	As previously stated, *Corbicula fluminea* has a wide ecological tolerance which allows it to establish populations in many fresh and brackish water environments in Ireland. The species can live in both freshwaters and brackish waters (to an upper salinity limit of 14 -17 psu). It can inhabit rivers, lakes, reservoirs, canals, streams and estuaries with silt, mud, sand or gravel substrates (McMahon 1999; reviewed Global Invasive Species Database 2005). The species has a preference for lotic conditions and is generally intolerant of pollution (reviewed Global Invasive Species Database 2005). The majority of freshwaters in Ireland are considered suitable for establishment with the exception of a small number of headwater rivers and lakes located in non-limestone areas, which are naturally acidic and poorly-buffered with a pH <5.6 and oligotrophic (in the case of lakes) (Lucy *et al*. 2012). Indeed, Lucy *et al*. (2012), "found that only 0.9% of 1,030 Irish rivers and 2.1% of 290 lakes throughout the island have lower probability to be colonised by *C. fluminea* due to their low average pH level. There are no rivers or lakes in Ireland that have a calcium level that will prevent *C. fluminea* from establishing reproducing populations."
3.02	How important is the expected spread of this organism in Ireland by natural means (minimal, minor, moderate, major or massive)?	MAJOR	VERY HIGH	Within colonised systems, passive downstream spread is likely to occur with water currents. Pediveliger larvae or small juveniles (< 2mm), released by the adults, can remain suspended in the water column and be transported long distances on water currents prior to settlement. The presence of a sticky byssal thread can act as a dragline to help keep the juvenile clams suspended in the water. The thread can also aid natural dispersal by facilitating attachment to floating plant material travelling downstream (reviewed in CABI 2012 and Lucy *et al*. 2012). In Ireland, *Corbicula fluminea* is considered to have invaded the tidal section of the River Nore from the population in the adjoining Rive Barrow, as a result of natural dispersal by the tide. There is some debate on the ability of waterfowl, fish or mammals to spread *Corbicula fluminea* (CABI 2012; Lucy *et al*. 2012). According to McMahon (1982; as cited in CABI 2012), the pediveliger larvae and juveniles can be transported on the feet or feathers of aquatic birds, dispersing *Corbicula fluminea* up and downstream of rivers (McMahon 1982 as cited in CABI 2012). However, there is little actual evidence to support this (reviewed in Rosa *et al*.

Stage 2 - Detailed assessment: Section C - Spread

This section evaluates the probability of spread of an organism within Ireland. Spread is defined as the expansion of the geographical distribution of an organism within the risk assessment area.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				2012). This mechanism of spread could, in theory, facilitate further introductions from abroad.
3.03	How important is the expected spread of this organism in Ireland by human assistance (minimal, minor, moderate, major or massive)?	MAJOR	VERY HIGH	According to Lucy *et al*. (2012), who gave an assessment of the potential future spread of *Corbicula fluminea* in Ireland, "Considering the connectivity and proximity of Irish river basins, existing canals (Grand and Royal) and the fact that most of the lakes and rivers are suitable for colonisation, we predict that the spread of *C. fluminea* will be rapid throughout the island's freshwaters, and that most of the spread will be associated with the human activity."
3.04	Within Ireland, how difficult would it be to contain the organism (minimal, minor, moderate, major or massive)?	MAJOR	HIGH	*Corbicula fluminea* has already established over a prohibitively large area of Ireland to prevent further spread. Further spread throughout the main Shannon system, its many sub-catchments (e.g. River Suck and River Inny systems), and the Shannon-Erne waterway will most likely occur. The implementation of and adherence to strict biosecurity measures may slow the spread of *Corbicula fluminea* to catchments which are geographically isolated from presently colonised areas. These currently include the Corrib and Moy systems in the west of Ireland, the Slaney in the south-east of Ireland, the Lee and Blackwater in the south-west of Ireland among many others. However, this would necessitate enforced restrictions on the movement of anglers, boaters and other water-users to such areas and full biosecurity compliance from stakeholders, which is not likely to occur.
3.05	What proportion (%) of the area in Ireland suitable for establishment, if any, has already been colonised by the organism?	0% -10%	HIGH	As previously described, *Corbicula fluminea* is known to have established in sections of three river systems in Ireland to date; the River Shannon, River Barrow and River Nore. However, the majority of habitat suitable for colonisation in Ireland has not been colonised to date (Lucy *et al*. 2012).
3.06	What proportion of the area in Ireland suitable for establishment, if any, do you expect to have been invaded by the organism five years from now (including any current presence)?	11% - 33%	MEDIUM	Based on its invasion history elsewhere in the world, *Corbicula fluminea* will spread rapidly throughout Ireland (Lucy *et al*. 2012). It is likely that the clam has already expanded beyond its known range and new populations will be detected in the next five years in catchments which are presently colonised and in catchments not yet known to be colonised. There may be a lag phase of a number of years between the introduction

Stage 2 - Detailed assessment: Section C - Spread

This section evaluates the probability of spread of an organism within Ireland. Spread is defined as the expansion of the geographical distribution of an organism within the risk assessment area.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				of *Corbicula fluminea* to a water and its detection (Caffrey *et al*. 2011) as new populations are often recorded only after they become abundant and more conspicuous to water users.
3.07	What other timeframe would be appropriate to estimate any significant further spread of the organism (10, 20, 40, 80 or 160 years)? Please comment on why this timeframe is chosen.	10 years	MEDIUM	The spread of *Corbicula fluminea* is likely to be rapid throughout Irish freshwaters (Lucy *et al*. 2012).
3.08	In this timeframe, what proportion of the area (including any currently occupied areas) is likely to have been invaded by this organism?	34% - 67%		The spread of *Corbicula fluminea* is likely to be rapid throughout Irish freshwaters (Lucy *et al*. 2012).
3.09	Based on the answers to questions on the potential for establishment and spread in Ireland, define the area endangered by the organism. Be as specific as possible. If available, provide a map showing the area most likely to be endangered.	REFER TO JUSTIFICATION BOX	HIGH	There is an abundance of suitable habitat available in Ireland for *Corbicula fluminea* (Lucy *et al*. 2012). The species can live in both freshwaters and brackish waters (to an upper salinity limit of 14 -17 psu). It can inhabit rivers, lakes, reservoirs, canals, streams and estuaries with silt, mud, sand or gravel substrates (McMahon 1999; reviewed Global Invasive Species Database 2005). The species has a preference for lotic conditions and is generally intolerant of pollution (reviewed Global Invasive Species Database 2005). The majority of freshwaters in Ireland are considered suitable for establishment with the exception of a small number of headwater rivers and lakes located in non-limestone areas, which are naturally acidic and poorly-buffered with a pH <5.6 and oligotrophic (in the case of lakes) (Lucy *et al*. 2012). Lucy *et al*. (2012) "found that only 0.9% of 1,030 Irish rivers and 2.1% of 290 lakes throughout the island have lower probability to be colonised by *C. fluminea* due to their low average pH level. There are no rivers or lakes in Ireland that have a calcium level that will prevent *C. fluminea* from establishing reproducing populations."
3.10	Estimate the overall potential for future spread for this organism in Ireland (very slowly, slowly, moderately, rapidly or very rapidly). Use the justification box to indicate any key issues .	RAPIDLY	HIGH	As previously mentioned, an assessment by Lucy *et al*. (2012) on future spread, stated that the spread of *Corbicula fluminea* is likely to be rapid throughout Irish freshwaters with human-mediated spread responsible for the majority of new introductions.

Stage 2 - Detailed assessment: Section D - Impact *This section evaluates the probability of impact of an organism within Ireland.*				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
4.01	How great is the economic loss caused by the organism within its global distribution (excluding Ireland), including the cost of any current management?	MAJOR	HIGH	According to a review by CABI (2012), "In the USA, *C. fluminea* has caused millions of dollars worth of damage to intake pipes used in the power and water industries. Large numbers, both dead or alive, clog water intake pipes and the cost of removing them is estimated at about a billion US dollars each year [Global Invasive Species Database 2005]. Juvenile *C. fluminea* get carried by water currents into condensers of electrical generating facilities where they attach themselves to the walls via byssus threads, growing and ultimately obstructing the flow of water. Several nuclear reactors have had to be closed down temporarily in the USA for the removal of *Corbicula* from the cooling systems (Isom 1986). In Ohio and Tennessee where river beds are dredged for sand and gravel for use as aggregation material in cement, the high densities of *C. fluminea* have incorporated themselves in the cement, burrowing to the surface as the cement starts to set, weakening the structure (Sinclair and Isom 1961). Isom (1986) has reviewed the invasion of *C. fluminea* of the Americas and the biofouling of its waters and industries. In the United States *Corbicula* sp. is consider a pest species (Counts 1981; Isom 1986). In power plant facilities they can clog condenser tubes (Potter and Liden 1986). In the United States alone, cost damages in a nuclear station by *C. fluminea* were estimated at US $2.2 billion annually in the early 1980s (OTA 1993). In the Delta-Mendota Canal, with a deficient design, the accumulation of sediment and *Corbicula* clams reduced the canal capacity (Arthur and Cederquist 1976). In South America fouling problems were only recorded in power plants in Brazil in 2000 (Zampatti and Darrigan 2001). In Russia there are reports of biofouling problems in reservoirs by *Corbicula* sp. in numerous locations: southern Primorye, Sakhalin and Khabarovsk (Yanov and Rakov 2002). Control methods in the power plant industry are reviewed by Post *et al*. (2006). European populations of Asian clams have not caused any major economic impact in industrial facilities (Swinnen *et al*. 1998; Paunovic *et al*. 2007). However, measures need to be taken before situations arise. Bachmann *et al*. (1997) on the Mosel River, states "the structure and the dynamics of these populations must now be carefully observed, in order to prevent possible economic and ecosystem damages" and Strauss (1982) refers to a French design system that manages to exclude fouling bivalves from cooling units."

Stage 2 - Detailed assessment: Section D - Impact

This section evaluates the probability of impact of an organism within Ireland.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
4.02	How great has the economic cost of the organism been in Ireland from the time of introduction to the present? Exclude any costs associated with managing the organism from your answer.	MINOR	HIGH	Only minor costs have been incurred to date by agencies such as Inland Fisheries Ireland (IFI) and various academic institutes (Sligo IT, TCD, QUB and UCD) undertaking field research on the distribution and population characteristics of the species where it is present in Ireland (e.g. Caffrey *et al*. 2011).
4.03	How great is the economic cost of the organism likely to be in the future in Ireland? Exclude any costs associated with managing the organism from your answer.	MODERATE	MEDIUM	According to Lucy *et al*. (2012), "potential economic damage in Ireland may include interference with power plant operation, drinking water abstraction from lakes and other industries using raw water". There may also be financial implications if conservations goals such as those specified in the EC Habitats Directive and the EU Water Framework Directive are under threat. Further to the above, if *Corbicula fluminea* has a detrimental effect on the abundance of important angling species such as Atlantic salmon, Brown Trout or Shad, this has the potential to incur economic costs due to reduced angling revenue and related income.
4.04	How great have the economic costs of managing this organism been in Ireland from the time of introduction to the present?	MINOR	HIGH	No specific date is available to provide figures on this. However, only minor costs have been incurred to date by agencies such as IFI which trialled a number of methods to control the clams in the River Barrow (CAISIE 2013). IFI and others have also incurred some costs promoting biosecurity practices among stakeholders to prevent the further spread of the species in Ireland (CAISIE 2013). Furthermore, some minor costs have been incurred supporting research conducted on effective disinfection procedures to prevent spread (Barbour *et al*. 2013).

Stage 2 - Detailed assessment: Section D - Impact *This section evaluates the probability of impact of an organism within Ireland.*				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
4.05	How great is the economic cost of managing this organism likely to be in the future in Ireland?	MODERATE	LOW	The projected annual costs to manage *Corbicula fluminea* are difficult to quantify and may depend on the magnitude of future infestations. Those which threaten aquatic habitats and species may incur control and habitat remediation costs. There may be costs associated with minimising the impact to water abstraction infrastructure in such waters. There may also be costs associated with implementing biosecurity measures to protect waterways.
4.06	How important is environmental harm caused by the organism within its global distribution?	MAJOR	VERY HIGH	This is reviewed in Lucy *et al*. 2012 as follows: "*Corbicula* is known to be one of the most aggressive freshwater invaders having strong economic and ecological impacts (McMahon 1982, 1999; Phelps 1994; Karatayev *et al*. 2005, 2007; Mackie and Claudi 2010). In the United States it has impacted municipal, agricultural, and industrial raw water systems (McMahon 1983, 1999). The most important economic impacts of *C. fluminea* include macrofouling of raw water systems (particularly those of fossil- fueled or nuclear power stations), and enhancement of sedimentation rates in canals (reviewed in McMahon 1999). The total damage caused by *C. fluminea* for US industries in 1986 alone, over two decades ago, was estimated at $1 billion (Isom 1986). The ecological impacts of *C. fluminea* are associated with its filtering activity. Asian clams occur in high densities over large areas, they can filter large volumes of water in short periods of time, subsequently depositing vast quantities of organic matter on the bottom, increasing benthic pelagic coupling, improving water clarity and competing with zooplankton for food. As an ecosystem engineer, *C. fluminea* imposes various impacts on habitat structure, biomineralisation, oxygenation, and benthic and planktonic community structure (Karatayev *et al*. 2005, 2007). Both the economic and ecological impacts of *C. fluminea* will depend on their population density in a given waterbody, which in turn depends on the prevalent substrate type, food availability, oxygen concentration, temperature regime and the waterbody morphometry (reviewed in Karatayev *et al*. 2005)."

Stage 2 - Detailed assessment: Section D - Impact

This section evaluates the probability of impact of an organism within Ireland.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
4.07	How important has the impact of the organism on biodiversity* been in Ireland from the time of introduction to the present? *e.g. decline in native species, changes in community structure, hybridisation.	MINOR	LOW	This has not been studied in any detail in Ireland to date. However, in highly infested areas such as the tidal River Barrow, *Corbicula fluminea* have attained very high density populations (up to 9,636 clams m^{-2}) (Caffrey *et a*l. 2011) with more recent maximum densities of up to 13,667 clams m^{-2} recorded (Sheehan *et al.* 2012). Percentage cover of clams in the lower tidal section of the River Barrow can be up to100 % and the clams can completely dominate the river bed substrates to a sediment depth of *c.* 15 cm deep (authors, personal observations). This represents a major change to this habit which is designated as a Special Area of Conservation under the EU Habitats Directive.
4.08	How important is the impact of the organism on biodiversity likely to be in the <u>future</u> in Ireland?	MODERATE / MAJOR	MEDIUM	The extensive establishment of *Corbicula fluminea* in large sections of the lower River Barrow, and to a lesser extent River Nore, could pose a threat to conservation fish species such as Twaite and Allis Shad; Sea, River and Brook Lamprey; and Smelt all of which use these areas of river as spawning grounds (Caffrey *et al*. 2012). Shad and smelt are broadcast spawners over benthic substrates and their larvae typically use the substrates as a development refuge (Seán Rooney, IFI, personal communication). Other native bivalve species, including the conservationally important Freshwater Pearl Mussel (a River Nore species), the diminutive Sphaeriidae (Pea / Fingernail Clams) and the large freshwater *Anodonta* mussels (Swan and Duck Mussels) are also considered to be under threat from direct competition from *Corbicula fluminea* for habitat and food resources. There is some potential for *Corbicula fluminea* to clog the gravel-dominated spawning grounds of Atlantic Salmon, Brown Trout and Sea Trout if it can establish large populations in these fast-flowing river and stream habitats.
4.09	How important has alteration of ecosystem function* caused by the organism been in Ireland from the time of introduction to the present? *e.g. habitat change, nutrient cycling, trophic interactions	MINOR	HIGH	This has not been studied in any detail in Ireland to date. Similar impacts as outlined in relation response to Questions 4.06 are likely to be occurring in heavily infested sites such as the lower River Barrow.

Stage 2 - Detailed assessment: Section D - Impact *This section evaluates the probability of impact of an organism within Ireland.*				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
4.10	How important is alteration of ecosystem function caused by the organism likely to be in Ireland in the future?	MODERATE / MAJOR	HIGH	This is dependent on the magnitude of future infestations. Impacts outlined in relation Questions 4.06 are likely in infested sites.
4.11	How important has decline in conservation status* caused by the organism been in Ireland from the time of introduction to the present? *e.g. sites of nature conservation value, WFD classification, etc.	MINIMAL	VERY HIGH	There has been no decline in conservation status reported to date.
4.12	How important is decline in conservation status caused by the organism likely to be in the future in Ireland?	MAJOR	VERY HIGH	Declines in conservation status are possible in infested sites, particularly if specific conservation species are threatened. This may have implications under the EU Habitats Directive and affect overall ecological status under the EU Water Framework Directive.
4.13	How important is social or human health harm (not directly included in economic and environmental categories) caused by the organism within its global distribution?	MODERATE	HIGH	According to CABI (2012), "The major concern in terms of social impact is *Corbicula* as a possible vector of diseases. The high abundances of Corbiculidae family and the vast and wide range of organisms that use bivalves as a final or secondary host are indeed responsible for health problems in its native range in humans and animals (Sousa *et al*. 2008). *Echinostoma* sp. is the most referenced parasite within *Corbicula* sp. detected for the first time by Bonne (1941) in *Corbicula rivalis* 'Busch' Philiphi 1850. Echinostomiasis is spread over South-East Asia and the Far East (mainland China, Taiwan, India, Korea, Malaysia, Philippines, and Indonesia) (Huffman and Fried 1990). *Corbicula* is one of the hosts and some parasite forms cause severe diseases in man, and are still a public health problem in endemic areas. Pathway transmission is by eating clams raw or barely cooked (Carney *et al*. 1980). A case study in Lake Lindu in Sulawesi showed a high rate of infection in some parts of the valley, reaching 96% with *Echinostroma lindonensis* (= *E. echinatum*). The situation changed when *Tilapia mossambicus* was introduced into Lake Lindu and began feeding on the veliger stage of *Corbicula* clams, leading this species almost to extinction. Therefore, the rates of infection decreased in Sulawesi and now echinostomiasis is reported as an historical disease (Kusharyono and Sukartinah 1991). The prevalence of infection ranges from 44% in the Philippines to 5% in mainland China, and from 50% in northern Thailand to 9% in Korea. This also represents a social and economic problem in the affected countries, since it is

Stage 2 - Detailed assessment: Section D - Impact *This section evaluates the probability of impact of an organism within Ireland.*				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
				prevalent in remote rural places among low-wage earners and in women of child-bearing age, and is aggravated by social economical factors (Graczyk and Fried 1998). There exists a wide variety of parasites in the Corbiculidae and their success as disease vectors is enhanced by *Corbicula* sp. abundance and distribution (Darrigran 2002; Sousa *et al.* 2008)".
4.14	How important is social or human health harm (not directly included in economic and environmental categories) caused by the organism within Ireland?	MINIMAL	MEDIUM	There has been no such harm reported to date.
4.15	How important is it that genetic traits of the organism could be carried to other organisms / species, modifying their genetic nature and making their economic, environmental or social effects more serious?	MINIMAL	MEDIUM	There is no evidence to suggest that this occurs.
4.16	How important is the impact of the organism as food, a host, a symbiont or a vector for other damaging organisms (e.g. diseases)?	MODERATE	MEDIUM	Refer to response to Question 4.13.
4.17	How important might other impacts not already covered by previous questions be resulting from introduction of the organism? Specify in the justification box.	MINIMAL	HIGH	All known impacts have been covered elsewhere in this document.
4.18	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 Ireland?	MODERATE	HIGH	The only known predator present in Ireland which has been recorded elsewhere as preying on *Corbicula fluminea* is the Common Carp (McMahon 1983 as cited in CABI 2012). Carp are only locally distributed in Ireland being mostly confined to private pond fisheries. Therefore, they have a very limited capacity to control *Corbicula fluminea*. In any case, Carp are very unlikely to be introduced as a bio-control agent, as it itself is a potentially invasive non-native species.

Stage 2 - Detailed assessment: Section D - Impact *This section evaluates the probability of impact of an organism within Ireland.*				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
4.19	Indicate any parts of Ireland where economic, environmental and social impacts are particularly likely to occur. Provide as much detail as possible, where possible include a map showing vulnerable areas.	REFER TO JUSTIFICATION BOX	HIGH	Economic, environmental and social impacts are possible wherever abundant populations of *Corbicula fluminea* establish. In general, as stated previously, there is an abundance of suitable habitat available in Ireland for *Corbicula fluminea* (Lucy *et al*. 2012). The species can live in both freshwaters and brackish waters (to an upper salinity limit of 14 -17 psu). It can inhabit rivers, lakes, reservoirs, canals, streams and estuaries with silt, mud, sand or gravel substrates (McMahon 1999; reviewed Global Invasive Species Database 2005). The species has a preference for lotic conditions and is generally intolerant of pollution (reviewed Global Invasive Species Database 2005). The majority of freshwaters in Ireland are considered suitable for establishment with the exception of a small number of headwater rivers and lakes located in non-limestone areas, which are naturally acidic and poorly-buffered with a pH <5.6 and oligotrophic (in the case of lakes) (Lucy *et al*. 2012).
4.20	Estimate the overall potential impact of this organism in Ireland. Use the justification box to indicate any key issues.	MAJOR	HIGH	*Corbicula fluminea* is considered to pose major risk to native biodiversity, native ecosystems and conservation goals as well as having the potential to cause negative socio-economic impacts due to its capacity to spread rapidly and establish dense populations.

Stage 2 - Detailed assessment: Section E - Conclusion *This section requires the assessor to provide a score for the overall risk posed by an organism, taking into account previous answers to entry, establishment, spread and impact questions.*				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
5.01	Estimate the overall risk of this organism in Ireland (noting answers given in 1.11, 2.16, 3.10 & 4.20).	MAJOR	HIGH	*Corbicula fluminea* is considered to pose a major risk to native biodiversity, native ecosystems and conservation goals as well as having the potential to cause negative socio-economic impacts due to its capacity to spread rapidly and establish dense populations.

Stage 2 - Detailed assessment: Section F – Additional questions

This section is used to gather information about the potential effects of climate change on the risk posed by an organism. It is also an opportunity for the risk assessor to highlight high priority research that could help improve the risk assessment.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
6.01	What aspects of climate change, if any, are most likely to affect the risk assessment for this organism?	REFER TO JUSTIFICATION BOX	LOW	Climate change is expected to increase water temperatures over time in Ireland, with increased periods of drought in summer and higher rainfall in winter leading to more flooding events (Desmond *et al*. 2008). Climate change is not considered to affect the risk assessment for this species. The lower temperature limit for *Corbicula fluminea* is considered to be between 0 and 2^{o}C, and the upper temperature limit is 37^{o}C (reviewed in Lucy *et al*. 2012).
6.02	What is the likely timeframe for such changes (5, 10, 15 , 20, 50 or 100 years)?	N/A		
6.03	What aspects of the risk assessment are most likely to change as a result of climate change	N/A	LOW	
6.04	If there is any research that would significantly strengthen confidence in the risk assessment, please note this here. If more than one research area is provided, please list in order of priority.	YES		At present there is a paucity of information to accurately assess the impact that *Corbicula fluminea* is or will have on native species and ecosystems in Ireland. Research in this area is likely to expand in the coming years as this species becomes further established. The economic impacts of the species in Ireland should also become clearer as *Corbicula fluminea* expands its range in the country. This risk assessment should be updated in future in line with any such developments.

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