Risk Assessment of *Astacus astacus*

Name of Organism:	*Astacus astacus* L. – Noble Crayfish
Objective:	Assess the risks associated with this species in Ireland
Version:	Final 15/09/2014
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Expert reviewer	Julian Reynolds

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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.

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Version Control Table

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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?		*Astacus astacus* (Linnaeus 1758), *Astacus astacus colchicus*, (Kessler 1876), *Astacus fluviatilis* (Fabricius 1775), *Cancer astacus* (Linnaeus 1758), *Potamobius fluviatilis balcanicus* (S. Karaman 1929); Noble Crayfish, Red-footed Crayfish, European Crayfish, Broad-clawed Crayfish, Red-clawed Crayfish, Broad-fingered Crayfish, River Crayfish. *Astacus astacus* is comprised of 3 sub-species: *Astacus astacus astacus* (widespread), *Astacus astacus balcanicus* (Greece and Macedonia) and *Astacus astacus colchicus* (Georgia) (Edsman *et al*. 2010). *Astacus astacus* has features that distinguish it from other crayfish species. However, smaller specimens could be confused with other species to the untrained eye (Souty-Grosset *et al*. 2006 as cited in GB Non-Native Species Secretariat 2011).
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.	-	*Astacus astacus* are usually dark brown or black on the dorsal side, and olive-brown on the ventral side. They are usually not more than 150 mm in total length (tip of rostrum to end of telson); however, specimens of 170 mm and 270 g have been reported. The claws are broad, with well-formed bases, red-brown on the ventral side and rough on the dorsal side. The carapace is smooth but with small granular tubercles on the sides. The rostrum is flat with a pair of lateral spines, and a keel toothed near the tip (reviewed in Sabapathy Allen 2014). A more comprehensive description of distinctive morphological characters is provided in Souty-Grosset *et al*. (2006).
5	Does a relevant earlier risk assessment exist? (give details of any previous risk assessment for Ireland)	YES	In Ireland, a preliminary risk assessment was previously carried out. This was a prioritisation risk assessment as part of the Risk Analysis and Prioritisation for Invasive and Non-native Species in Ireland and Northern Ireland (Kelly *et al*. 2013). It designated *Astacus astacus* as a 'high risk' invasive species.
6	If there is an earlier Risk Assessment is it still entirely valid, or only partly valid?	PARTIAL	

Stage 1 - Organism Information *The aim of this section is to gather basic information about the organism.*			
N	**QUESTION**	**RESPONSE**	**COMMENT**
7	Where is the organism native?		Andorra; Austria; Belarus; Belgium; Bosnia and Herzegovina; Bulgaria; Croatia; Czech Republic; Denmark; Estonia; Finland; France; Georgia (Abkhaziya, Adzhariya, Gruziya); Germany; Greece; Hungary; Latvia; Lithuania; Macedonia, Moldova; Netherlands; Poland; Romania; Russian Federation (Kaliningrad); Serbia; Slovakia; Slovenia; Switzerland (Edsman *et al*. 2010). Note: The original range of *Astacus astacus* is difficult to determine as it has been changed during history due to human-mediated transplantation (Skurdal and Taugbøl 2002). The definition of native can be subjective; many countries use the year 1500 as a watershed (Holdich *et al*. 2009). *Astacus astacus* is believed to be introduced by man to Norway and Sweden in the Middle Ages, but is considered native there, being part of the fauna for several centuries. It may also have been moved into Western Europe (e.g. France, Belgium etc.) by man (Souty-Grosset *et al*. 2006).
8	What is the current global distribution of the organism (excluding Ireland)?		Britain, Cyprus; Italy, Liechtenstein; Luxembourg; Montenegro; Morocco; Ukraine; and Britain in addition to the countries listed in answer to Question 7 (Edsman *et al*. 2010).
9	What is the current distribution of the organism in Ireland?	-	This species is not present in Ireland.
10	Is the organism known to be invasive anywhere in the world?		The authors could find limited information documenting that *Astacus astacus* is invasive in countries where it has been introduced (apart from references to how crayfish introductions in general may impact habitats and provide competition for existing crayfish species). This may be due to a lack of published studies or its confined distribution in some introduced countries e.g. it is only recorded at two locations in Britain (GB Non-Native Species Secretariat 2011). However, in areas where *Astacus astacus* is non-native there is some evidence to suggest it can outcompete or exclude populations of indigenous White-clawed Crayfish (e.g. Lachat and Laurent 1988; Souty-Grosset *et al*. 2006). The species was introduced to Lake Steinsfjorden in Norway the 1850s where, since the 1900s, they have been intensively harvested for food (reviewed in Skurdal *et al*. 2002).

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)?	MODERATE	HIGH	
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. Aquarium trade 2. Food trade for humans or fish 3. Fish stocking 4. Angling	HIGH	The 'aquarium trade' and 'food trade for humans and fish' are the principal pathways responsible for the introduction and establishment of non-native crayfish in Europe to date (Holdich 2002). Crayfish also have the potential to be inadvertently introduced as a contaminant of fish stocking' and 'angling' practices or if used as live bait for angling.

Pathway 1 – Aquarium trade

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	Although there is no official record of this particular species being sold in Ireland *via* the aquarium trade, a number of other potentially invasive, non-native crayfish are periodically for sale in Irish aquarium shops and can be purchased on the internet (Reynolds and O'Keeffe 2009). There is potential for the release of such crayfish to the wild from aquarium dumps.
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	There is no specific information available to assess this. Therefore, it is rated as unlikely. However, potentially invasive, non-native crayfish are imported into Ireland for sale every year (Reynolds and O'Keefe 2009).
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	As the organism would be deliberately distributed for trade and transported in an aquatic environment, survival is highly likely.

Pathway 1 – Aquarium trade				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
1.07	How likely is the organism to arrive during the months of the year appropriate for establishment?	VERY LIKELY	VERY HIGH	Crayfish can survive an introduction at any time of year. The introduction of a single berried female could result in a population becoming established (summer to autumn period). Alternatively, it would take a minimum of two individuals (male and female, respectively) capable of breeding to establish a viable population.
1.08	How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	MODERATELY LIKELY	HIGH	The deliberate introduction of crayfish to a suitable habitat as an aquarium dump is the most likely mechanism for transfer from this pathway. This is a phenomenon observed in other countries (GB Non-Native Species Secretariat 2011). Alternatively, escape may be dependent on how securely live crayfish are stored and their proximity to a suitable water for survival – they do have some ability to walk over-land to access a watercourse.
1.09	Estimate the overall likelihood of entry into Ireland based on this pathway?	LIKELY	MEDIUM	Although there is no specific information available to assess the entry of this crayfish species to Ireland *via* this pathway, it is known that a variety of non-native crayfish species are imported and available for sale in the country (Reynolds and O'Keeffe 2009). Therefore, it is considered likely.
1.10	Do other pathways need to be considered?	YES		

Pathway 2 – Food trade for humans or fish				
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	Non-native crayfish have been deliberately transferred to the wild to establish a food source for humans and fish in Europe (Holdich 2002; GB Non-Native Species Secretariat 2011)
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	Potential points of origin for these pathways are England, continental Europe and Scandinavia. Two wild populations of *Astacus astacus* are present in England (where the species is non-native), one of which established after a fish farm escape in the 1980s (Holdich 2002; GB Non-Native Species Secretariat 2011). In continental Europe and Scandinavia, the species is largely native or naturalised and widespread, although it is itself under pressure from other non-native crayfish species

Pathway 2 – Food trade for humans or fish				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
				(Holdich 2002). Live non-native crayfish have occasionally turned up in Irish fishmongers (Reynolds and O'Keeffe 2009), although there is no specific reports of this being the case for *Astacus astacus*. Deliberate dumping of surplus or undersized crayfish may occur. Inadvertent transfer to the wild *via* this pathway is considered unlikely as the crayfish may be in a weakened state from cold storage. There are also reports of non-native crayfish being stocked as a food source for fish and being used as live bait for angling (GB Non-Native Species Secretariat 2011) but not, to date, in Ireland. Overall, It is considered unlikely that large numbers of *Astacus astacus* will travel by these pathways.
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?	LIKELY	HIGH	Unless legislation ensures that only cooked crayfish are traded, the crayfish would be kept alive when moved *via* these pathways to ensure their survival.
1.07	How likely is the organism to arrive during the months of the year appropriate for establishment?	VERY LIKELY	VERY HIGH	Refer to Pathway 1, Question 1.07.
1.08	How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	MODERATELY LIKELY	HIGH	This is most unlikely when live specimens are imported for the food trade as it would necessitate escape to a suitable habitat or a deliberate act of introduction. Direct transfer is assured if stocked as fish food source. Imported living crayfish are considered unlikely to be imported and stocked as fish food but more likely to be discarded live as surplus from the food trade.
1.09	Estimate the overall likelihood of entry into Ireland based on this pathway?	MODERATELY LIKELY	HIGH	Although there is no such instances reported to date in Ireland, it is considered moderately likely based on previous experiences from other countries (reviewed in Holdich 2002; GB Non-Native Species Secretariat 2011).
1.10	Do other pathways need to be considered?	YES		

Pathway 3 – 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)?	ACCIDENTAL	VERY HIGH	There is the potential for introduction as a contaminant of fish stocking.
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	HIGH	It is unlikely but fish stocking from foreign waters which have *Astacus astacus* has the potential to inadvertently transfer the species to Ireland.
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?	LIKELY	HIGH	The crayfish would be moved in association with the fish to be stocked giving a high chance of survival, except in conditions where the fish may prey on the crayfish during transit.
1.07	How likely is the organism to arrive during the months of the year appropriate for establishment?	LIKELY	VERY HIGH	Refer to Pathway 1, Question 1.07.
1.08	How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	LIKELY	MEDIUM	Direct transfer is very likely as the crayfish would be transported in water.
1.09	Estimate the overall likelihood of entry into Ireland based on this pathway?	UNLIKELY	MEDIUM	Although unlikely, there is some potential for introduction as a contaminant of fish stocking, if the fish are sourced from a location where crayfish are present.
1.10	Do other pathways need to be considered?	YES		

Pathway 4 – Angling				
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	VERY HIGH	The movement of angling equipment (particularly landing or keep nets and stink bags) from a foreign water has non-native crayfish has the potential to inadvertently introduce such species to Ireland. In addition, if used as live bait for angling there is potential for escape.

Pathway 4 – Angling				
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	HIGH	It is unlikely but there is an increased potential for the inadvertent spread of non-native crayfish in the absence of implementing appropriate biosecurity measures.
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?	MODERATELY LIKELY	HIGH	The crayfish are moderately likely to stay alive if kept damp and cool when inadvertently carried on angling gear. This would further depend on the duration of transfer. If used as live bait for angling, survival is highly likely.
1.07	How likely is the organism to arrive during the months of the year appropriate for establishment?	LIKELY	VERY HIGH	Refer to Pathway 1, Question 1.07.
1.08	How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	LIKELY	HIGH	Direct transfer is likely as angling gear such as keep nets would be redeployed into a receiving water. This is also the case for live bait.
1.09	Estimate the overall likelihood of entry into Ireland based on this pathway?	UNLIKELY	MEDIUM	Although unlikely, there is some potential for entry *via* this pathway if the angling gear has previously been used, and not subsequently disinfected, in a location where non-native crayfish are present.
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).	LIKELY	HIGH	The most likely pathways for non-native crayfish to gain entry to suitable waters in Ireland are considered to be through the deliberate introduction from an aquarium dump or through the food trade.

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')	NO	VERY HIGH	This species has not been recorded in the wild in Ireland to date or is not known to have been imported for sale available for sale in Ireland.
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?	LIKELY	HIGH	Climatic conditions in its native range (i.e. continental Europe and Scandinavia) are generally more extreme than Ireland, with colder winters and longer, warmer summers. The species has established populations at two locations in England, with no evidence of any significant spread to date since their introduction in the 1980s (GB Non-Native Species Secretariat 2011). This is at variance with that observed for some other non-native crayfish species in Britain (GB Non-Native Species Secretariat 2011). It is postulated that the summers and water temperatures do not get warm enough to support prolific population growth in England (GB Non-Native Species Secretariat 2011). This may also be the case in Ireland. Therefore, the survival and establishment of *Astacus astacus* populations in Ireland is considered likely, despite the uncertainty as to how prolific any population establishment would be.
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	Overall, abiotic conditions are not believed to be limiting in Ireland. *Astacus astacus* is capable of tolerating calcium levels of 2 - 3 mgl^{-1} Ca, which are lower than the limiting range (5 mgl^{-1} Ca) reported for our native† White-clawed Crayfish *Austropotamobius pallipes* (Lereboullet). Dissolved oxygen content above 3 - 4 mgl^{-1} is also required (Füreder *et al*. 2010). The temperature range for optimum growth is between 16 and 24 ^{o}C (Edsman *et al*. 2010), which is unlikely to restrict normal growth in the majority of suitable lowland freshwaters in Ireland (i.e. rivers, lakes, canals, ponds and reservoirs) where water temperatures, at least in shallow depths, can exceed 16 ^{o}C from early May to late August. Further to this, *Astacus astacus* requires at least 3 months where water temperatures exceed 15 ^{o}C for successful reproduction (Abrahamsson 1966; Abrahamsson 1971) and egg development (Pérez *et al*. 2003). They can be further restricted to the shallower parts of temperate lakes, above the thermocline, during the summer months (Skurdal *et al*. 1988; all as cited in Olsson 2005). († It is uncertain whether the White-clawed Crayfish is indigenous or may have been introduced to Ireland in medieval times or later (reviewed in Reynolds 2010). However, being the only freshwater crayfish species found in the wild in Ireland, and of international conservation importance

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
				because of this, it is referred to as a native species in this risk assessment.)
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	In their original range *Astacus astacus* exists in a range of habitat types such as rivers, lakes, canals, ponds and reservoirs, in both lowlands and upland areas, where shelter availability is high and calcium levels are at least 2 - 3 mgl^{-1} Ca (Souty-Grosset *et al*. 2006 as cited in Edsman *et al*. 2010). The organism prefers soft benthic conditions with some sand, and shelter provided by stones, logs, roots, or aquatic or marginal vegetation. It is not usually found in waters with a muddy substrate. It also prefers soft banks where it constructs simple burrows (reviewed in Edsman *et al*. 2010). There is an abundance of such habitats available for colonisation in Ireland.
2.05	How likely is it that establishment will occur despite competition from existing species in Ireland?	VERY LIKELY	VERY HIGH	Competition will occur from existing species but is highly unlikely to prevent establishment. Some macroinvertebrate species such as dragonfly larvae may compete with juvenile crayfish. Fish may also provide competition for food resources (GB Non-Native Species Secretariat 2011). It is highly likely that the native White-clawed Crayfish would provide direct competition for resources, where both occur. However, *Astacus astacus* is likely to be advantaged in this regard as it can grow faster and reach a larger final size than the White-clawed Crayfish (Lachat and Laurent 1988; Reynolds 1998;; Souty-Grosset *et al*. 2006).

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	VERY HIGH	Predation will occur from existing species such as perch, pike, heron, otter, mink and eels but is highly unlikely to prevent establishment. *Astacus astacus* is susceptible to the crayfish plague *Aphanomyces astaci* (Schikora) and this has decimated native populations of the species throughout continental Europe (Holdich 2002). The same crayfish plague has extirpated populations of White-clawed Crayfish in the Irish midlands since the 1980s (reviewed in Matthews and Reynolds 1992) but no further outbreaks have been reported.
2.07	How likely is it that establishment will occur despite existing management practices?	MODERATELY LIKELY	HIGH	In general, the public management of waterways is undertaken cognisant of ensuring biosecurity measures are in place to mitigate for the spread of aquatic invasive species. An increase in awareness by some private stakeholders of the threat from aquatic invasive species has also reduced this risk. Importation of crayfish to Ireland was thought to be prohibited under the Live Fish (restriction of importation) Order 1972 of the Fisheries Acts. However, it was recently concluded that the definition given for "fish" did not apply to freshwater crayfish and, therefore, may not be enforceable (Reynolds 2010). Nevertheless, such measures have been successful to date in preventing the spread of non-native crayfishes to this country (Reynolds 1998).
2.08	How likely is it that management practices in Ireland will facilitate the establishment of the organism?	UNLIKELY	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?	MODERATELY LIKELY	HIGH	In England, where two localised non-native populations of *Astacus astacus* are present, there has been no active attempt to eradicate this species (GB Non-Native Species Secretariat 2011). The organism is susceptible to crayfish plague, which has resulted in extinctions in mainland Europe (Holdich 2002) but this would not be a feasible measure to employ in Ireland as the White-clawed Crayfish is also highly vulnerable to this. The use of biocides (e.g. natural pyrethroides) is an option for a pond population but these are unlikely to work in a complex river catchment, or indeed in a canal or large lake. Trapping is an

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
				ineffective eradication method due to behavioural traits, habitat complexity and the burrowing nature of the species (Cosgrove *et al*. 2008; GB Non-Native Species Secretariat 2011).
2.10	How likely is it that the biological characteristics of the organism will facilitate its establishment?	LIKELY	HIGH	It is likely that *Astacus astacus* could establish in Irish freshwaters due to its relatively large size and its faster growth rate when compared with our native White-clawed Crayfish (Reynolds 1998).
2.11	How likely is it that the organism's capacity to spread will facilitate its establishment?	MODERATELY LIKELY	LOW	This is uncertain and would depend on the extent of initial introduction(s). In England, despite two introductions, one of which occurred in the 1980s, significant spread has not occurred to date (GB Non-Native Species Secretariat 2011). Based on this, it is anticipated that the species will achieve only a slow natural spread within Irish freshwater systems.
2.12	How likely is it that the organism's adaptability will facilitate its establishment?	LIKELY	HIGH	In general, crayfish are omnivorous having the ability to act as herbivores, detritivores and predators. This non-specific, polytrophic character provides good adaptability to facilitate establishment in suitable habitats with varying food resources.
2.13	How likely is it that the organism could establish despite low genetic diversity in the founder population?	LIKELY	MEDIUM	There is no information available to comment in detail on this. However, low genetic variation in Irish populations of *A. pallipes* has not hindered their spread (Gouin *et al*. 2003).
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	Based on knowledge of its biological character and ecological requirements in its native and introduced range, *Astacus astacus* is very likely to establish in Ireland as climatic and abiotic conditions are suitable and there are a wide range of habitats available for colonisation. In Lake Steinsfjorden, Norway, where *Astacus astacus* was introduced in the 1850s, the harvest yield estimated from 1910 -1979 was about 1 - 6.5 kg/ha (reviewed in Zimmerman 2009), with a subsequent decline to 0.7 – 4.7 kg/ha observed after this period due to fishing regulations, and the clogging of littoral areas with *Elodea canadensis* which likely reduced the lake population (reviewed in Skurdal *et al*. 2002). This provides some indication of the potential population that can be achieved in introduced waters.

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
2.15	If the organism does not establish, then how likely is it that transient populations will continue to occur?	UNLIKELY	VERY HIGH	*Astacus astacus* individuals can live for 20 years (Souty-Grosset *et al*. 2006). Transient populations are unlikely as it is considered very likely from the risk assessment review that reproducing populations would establish after introduction.
2.16	Estimate the overall likelihood of establishment. Mention any key issues in the comments box	VERY LIKELY	VERY HIGH	The information assembled in Section B suggests that it is very likely that *Astacus astacus* can establish in Ireland if introduced.

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	*Astacus astacus* can exist in a range of habitat types such as rivers, canals lakes, ponds and reservoirs, in both lowlands and upland areas, where shelter availability is high and calcium levels are at least 2 - 3 mgl^{-1} Ca (Souty-Grosset *et al*. 2006 as cited in Edsman *et al*. 2010). The organism prefers soft benthic habitats with some sand, and shelter provided by stones, logs, roots, or aquatic or marginal vegetation. It is not usually found in waters with a muddy substrate. It also prefers soft banks where it constructs simple burrows (reviewed in Edsman *et al*. 2010). There are an abundance of such habitats available for colonisation in Ireland.
3.02	How important is the expected spread of this organism in Ireland by natural means (minimal, minor, moderate, major or massive)?	MODERATE	MEDIUM	This is uncertain and would depend on the extent of initial introduction(s). In England, despite two introductions, one of which occurred in the 1980s, significant spread has not occurred to date (GB Non-Native Species Secretariat 2011). Based on this, slow natural spread is moderately likely within Irish freshwater systems.
3.03	How important is the expected spread of this organism in Ireland by human assistance (minimal, minor, moderate, major or massive)?	MODERATE	HIGH	Anthropogenic-mediated spread is more likely than natural spread in Ireland, especially between catchments. Such inter-catchment transfers may be (illegally) conducted to provide local food sources for humans or fish, or the species may be transferred by anglers for use as live fish bait.
3.04	Within Ireland, how difficult would it be to contain the organism (minimal, minor, moderate, major or massive)?	MAJOR/ MASSIVE	HIGH	This depends on the response time between an introduction occurring and the reaction enacted to contain it. It also depends on the nature of the water that is stocked or colonised. Containment would be moderately difficult but feasible in a closed or semi-closed system (i.e. pond, land-locked water or locked canal) but much more difficult in an open-water system (e.g. river catchment). In general, we have been unsuccessful in containing other introduced invertebrates.
3.05	What proportion (%) of the area in Ireland suitable for establishment, if any, has already been colonised by the organism?	NONE	VERY HIGH	This species has not been recorded in Ireland to date.
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)?	N/A		The species is not present in Ireland.

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
3.07	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.	N/A		The species is not present in Ireland.
3.08	In this timeframe, what proportion of the area (including any currently occupied areas) is likely to have been invaded by this organism?	N/A		The species is not present in Ireland.
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 Question 3.01.
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 .	MODERATELY	HIGH	If introduced the potential for subsequent spread is very high, although the rate at which the species could spread is uncertain. This primarily depends on the number and quantity of introductions and the character of the waters they are introduced to.

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?	MINOR	LOW	There is a paucity of information in this regard. *Astacus astacus* has the potential to impact on fisheries by reducing the value of the angling resource by altering food-webs and habitat. Extensive burrowing could have implications on the stability of flood banks, bank erosion on rivers and dams/head walls (GB Non-Native Species Secretariat 2011).
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.	N/A		This species has not been recorded in Ireland to date.
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	LOW	See Question 4.01 for an overview of potential economic impacts. Competition with the protected *A. pallipes*, perhaps promoting its decline, is unquantifiable.
4.04	How great have the economic costs of managing this organism been in Ireland from the time of introduction to the present?	N/A		This species has not been recorded in Ireland to date.
4.05	How great is the economic cost of managing this organism likely to be in the future in Ireland?	MODERATE	MEDIUM	As potential impacts are uncertain, this would depend of the level of establishment and spread, if introduced. It would be vitally important to minimise any impact to the native White-clawed Crayfish that could be caused, either directly or indirectly, by *Astacus astacus*. This mitigation could perhaps be achieved by eradication, containment and control.
4.06	How important is environmental harm caused by the organism within its global distribution?			*Astacus astacus* is not noted for causing environmental harm within its global range (GB Non-Native Species Secretariat 2011).
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	N/A		This species has not been recorded in Ireland to date.
4.08	How important is the impact of the organism on biodiversity likely to be in the future in Ireland?	MAJOR	VERY HIGH	The establishment of *Astacus astacus* populations would represent a serious threat to the continued conservation of the indigenous White-clawed Crayfish in Ireland. The White-clawed Crayfish is an EU Habitats Directive protected Annex 2 listed species and classified as vulnerable

Stage 2 - Detailed assessment: Section D - Impact *This section evaluates the probability of impact of an organism within Ireland.*				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
				and rare in the IUCN Red List of threatened animals. It is also recognised to be of national importance, with legislation enacted to protect it under the Wildlife Act 1976 in Ireland. It is likely that both *Astacus astacus* and our native crayfish species would occupy similar ecological niches and habitats, and it is considered that *Astacus astacus* may displace the native crayfish due to its relatively large size and faster growing nature (Lachat and Laurent 1988; Reynolds 1998).
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	N/A		This species has not been recorded in Ireland to date.
4.10	How important is alteration of ecosystem function caused by the organism likely to be in Ireland in the future?	MODERATE	LOW	As 'ecosystem engineers', crayfish species have the ability to alter ecosystem function through food-web or habitat modification (Jones *et al*. 1997). The degree of change would likely depend on the extent of colonisation. Abrahamsson (1966) as cited in Zimmerman (2009) found that *Astacus astacus* can reduce the biomass of submerged vegetation, molluscs and leeches in a pond but after their extinction by crayfish plague, this biomass increased. An extrapolation of laboratory experiments conducted by Kholodkevich *et al*. (2005) indicated that *Astacus astacus* is capable of controlling no less than 40% of submersed macrophytes (notably *Chara vulgaris*) in a Russian lake. Therefore, it is possible that charophyte vegetation which is the keystone habitat in most large hard water lakes in Ireland (Champ 1993; Krause and King 1994), or indeed other such submerged vegetation, may be impacted with knock-on effects for some fish species and invertebrates (O'Grady *et al*. 2009) and overall ecosystem function.
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.	N/A		This species has not been recorded in Ireland to date.

Stage 2 - Detailed assessment: Section D - Impact

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

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
4.12	How important is decline in conservation status caused by the organism likely to be in the future in Ireland?	MAJOR	HIGH	The establishment of *Astacus astacus* may have detrimental impacts on our native White-clawed Crayfish populations in Ireland (refer to response to Question 4.08). This may have implications for the classification of ecological status under the EU Water Framework Directive and the conservation status under the EU Habitats 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?	MINOR	LOW	According to GB Non-Native Species Secretariat (2011) "Depending on the degree of spread there could be damage to fisheries and possible physical damage to flood banks etc. that may lead to flooding. There is no evidence that this species could burrow so extensively as to result in a flood bank failure, but additional studies may provide more information."
4.14	How important is social or human health harm (not directly included in economic and environmental categories) caused by the organism within Ireland?	N/A		This species has not been recorded in Ireland 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	HIGH	Reproductive interference may occur, but this species is not known to interbreed with the White-clawed Crayfish or other species.
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)?			*Astacus astacus* is an esteemed food organism in Europe. This species is susceptible to crayfish plague and could spread it to the native White-clawed Crayfish. It is known as a non-specific prey item of the invasive North American Mink (reviewed in GB Non-Native Species Secretariat 2011), which is already established in the wild in Ireland.
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	
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	Natural control by other organisms (bar the crayfish plague) is unlikely to influence expected impacts (i.e. displacement of the native White-clawed Crayfish).

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 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.	-		According to GB Non-Native Species Secretariat (2011), "Angling facilities and high quality aquatic habitats could suffer. Lowland rivers and other areas where flood defences play an important role may also be affected." Potential environmental impacts are possible wherever *Astacus astacus* would establish (i.e. rivers, lakes, canals, ponds and reservoirs with habitat characteristics as outlined in answer to Question 3.01).
4.20	Estimate the overall potential impact of this organism in Ireland. Use the justification box to indicate any key issues.	MAJOR	VERY HIGH	The primary potential impact of *Astacus astacus* in Ireland is the threat it poses to the native White-clawed Crayfish.

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	VERY HIGH	This crayfish species has the potential to seriously threaten the sustainability of native White-clawed Crayfish populations in Ireland.

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?		MEDIUM	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). In general, *Astacus astacus* survives well in temperate climates and areas with temperature extremes greater than those found in England and Wales (GB Non-Native Species Secretariat 2011). It is considered that this would also be the case in Ireland. Higher temperatures could favour this species, unless it impacted on dissolved oxygen levels, but severe floods could restrict its available range (J. Reynolds pers. comm.).
6.02	What is the likely timeframe for such changes (5, 10, 15, 20, 50 or 100 years)?	UNKNOWN		
6.03	What aspects of the risk assessment are most likely to change as a result of climate change		LOW	An increase in water temperatures could increase the growth and fecundity of *Astacus astacus* (Edsman *et al*. 2010; reviewed in Olsson 2005), and enhance its capability to displace native White-clawed Crayfish populations.
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	MEDIUM	As *Astacus astacus* is not present in the wild in Ireland, it is difficult to comprehensively evaluate the socio-economic, economic and environmental impacts that this species may have in Ireland. This is further hampered as it is indigenous / naturalised in continental Europe and the majority of Scandinavia and there is a paucity of information regarding its impacts, where it was recently introduced. Further analyses in this regard would be useful.

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