

Risk Assessment of *Procambarus* sp.

Name of Organism:	<i>Procambarus</i> sp. – Marbled 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 **Non-native species APplication based Risk Analysis (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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Stage 1 - Organism Information			
<i>The aim of this section is to gather basic information about the organism.</i>			
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?	NO	<p><i>Procambarus</i> sp.; Marbled Crayfish; Marmokrebs (Souty-Grosset <i>et al.</i> 2006). <i>Procambarus</i> sp. is now generally accepted as a parthenogenetic form of <i>Procambarus fallax</i> (Hagen 1870) (as originally suggested by Scholtz <i>et al.</i> 2002); and generally called <i>Procambarus fallax f. virginalis</i> (Martin <i>et al.</i> 2010) (J. Reynolds pers. comm.). A detailed account of the establishment of its identity is given in a review by Holdich (2011):</p> <p>According to Holdich (2011), "Molecular genetic studies have shown it to be a member of the North American crayfish family Cambaridae, and to belong to the genus <i>Procambarus</i>". "Initially, it was shown by molecular techniques that the nearest relative to this unknown species was <i>Procambarus (Ortmannicus) fallax</i> (Hagen, 1870) (Scholtz <i>et al.</i> 2002 [sic]). However, subsequent studies indicated that it was close to <i>Procambarus (Leconticambarus) alleni</i> (Faxon 1884) (Crandall 2005, pers. comm. to Holdich 2011). Sequencing of the cytochrome oxidase gene has shown that <i>Procambarus</i> sp. specimens from Austria, at least, were not the same as <i>Procambarus alleni</i> obtained from cultures in Austria, but were closer to <i>Procambarus (Pennides) spiculifer</i> (LaConte 1856) (Fetzner 2006 pers. comm. to Holdich 2011). Subsequent comparison of <i>P. alleni</i> with <i>Procambarus</i> sp. indicated marked differences in the morphology of <i>Procambarus</i> sp. and <i>Procambarus alleni</i> (Pöckl 2006 pers. comm. to Holdich 2011). Recently, Martin <i>et al.</i> (2010) have re-evaluated the status of Marmokrebs using morphological and molecular means. They are fairly certain that it is indeed the parthenogenetic form of <i>Procambarus fallax</i>, which is native to peninsular Florida and southern Georgia." "It can usually be distinguished from other <i>Procambarus</i> spp. by its marbled appearance and the small size of its chelipeds, which are weakly granulate (Pöckl <i>et al.</i> 2006; Souty-Grosset <i>et al.</i> 2006). However, Martin <i>et al.</i> (2010) found a single individual in Saxony which, although it was confirmed as Marmokrebs by molecular techniques, had rather different body patterns and a totally different rostrum shape".</p>
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)	NO	Refer to response to Question 2 above.

Stage 1 - Organism Information			
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N	QUESTION	RESPONSE	COMMENT
4	Describe the organism.	-	Marbled Crayfish are characterised by “small chelipeds and a marbled appearance on a brownish, dark brown, green or blue background; carpal spur present in adults, but not apparent in juveniles; rostrum triangular-shaped with broad base, shoulders shallow and acumen short, one pair of post-orbital ridges” (Holdich 2009). As it is solely a parthenogenetic species, only females are known to exist (Holdich 2009). Total length is \leq 13 cm but more often < 10 cm (Souty-Grosset <i>et al.</i> 2006). A more comprehensive description of distinctive morphological characters is provided in Souty-Grosset <i>et al.</i> (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 <i>et al.</i> 2013). It designated Marbled Crayfish 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).
7	Where is the organism native?		The native range of the Marbled Crayfish is unknown. The species was first discovered in aquaria in Germany in the mid-1990s (Scholtz <i>et al.</i> 2003; Vogt 2008). If it is similar to <i>P. fallax</i> , it is native to the southern states of the USA, from Georgia to peninsular Florida (Souty-Grosset <i>et al.</i> 2006).
8	What is the current global distribution of the organism (excluding Ireland)?		In Europe, Marbled Crayfish had been recorded from 15 locations up to 2012 – at least six of which represented established populations (reviewed in Chucholl <i>et al.</i> 2012). This includes 12 records in Germany (reviewed in Chucholl <i>et al.</i> 2012) and single records in Slovakia (Janský and Mutkovič 2010 as cited in Chucholl <i>et al.</i> 2012), Sweden (Bohman <i>et al.</i> 2013) and The Netherlands (Soes and van Eekelen 2006 as cited in Chucholl <i>et al.</i> 2012). A single specimen was recorded in Italy (Marzano <i>et al.</i> 2009). Elsewhere in the world, Marbled Crayfish have been recorded in Madagascar in numerous locations around the capital city of Antananarivo (Jones <i>et al.</i> 2008) and more recently at a single location in Japan (Faulkes <i>et al.</i> 2012).
9	What is the current distribution of the organism in Ireland?	-	This species is not present in the wild in Ireland.
10	Is the organism known to be invasive anywhere in the world?	YES	Marbled Crayfish are highly invasive in Madagascar where numerous high density populations have established (Jones <i>et al.</i> 2008). In Europe, previous to 2010, only one established population of Marbled Crayfish was known. However, by 2012, at least six established populations were documented (Chucholl <i>et al.</i> 2012). This is likely to have increased in the interim and will probably continue to increase in future as Marbled Crayfish are abundant in the European pet trade and there appears to be a lag phase of

Stage 1 - Organism Information

The aim of this section is to gather basic information about the organism.

N	QUESTION	RESPONSE	COMMENT
			several years between introduction and detection (Chucholl <i>et al.</i> 2012). It should be noted that there is a paucity of published studies to assess how invasive these populations are at present.

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 <u>significant</u> 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). The former is the most likely pathway of entry to Ireland as Marbled Crayfish are principally an aquarium species (Chucholl <i>et al.</i> 2012). 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	<p>Varieties of potentially invasive, non-native crayfish, including Marbled Crayfish, are periodically for sale in Irish aquarium shops and can be purchased on the internet (Reynolds and O'Keeffe 2009). In addition, Marbled Crayfish are also bred and traded among some aquarium hobbyists. Based on European experience to date, there is a high potential for the release of Marbled Crayfish to the wild from aquarium dumps (Chucholl <i>et al.</i> 2012). The species is considered highly attractive to aquarium hobbyists and its parthenogenetic character confers a high reproductive potential, allowing it to rapidly overpopulate an aquarium (Chucholl <i>et al.</i> 2012). This can result in aquarium dumps to the wild and threats to carry out such an act by aquarium hobbyists due to over-abundance in their aquaria have been documented (e.g. Holdich 2011). For example, single specimen obtained for an aquarium was reported as having produced around 100 individuals in 8 months (Scott 2005, <i>pers. comm.</i> as cited in Holdich 2011).</p> <p>Because of its parthenogenetic character, a single Marbled Crayfish is sufficient to establish a new population (Chucholl <i>et al.</i> 2012).</p>

Pathway 1 – Aquarium trade				
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	LOW	Specific information on the amount of imports to Ireland and subsequent trade occurring of Marbled Crayfish for aquaria in the country are unknown, but considered to be low. The species is available for purchase on the internet in Ireland, which confirms a certain level of internal trade occurs. There is also the potential for Marbled Crayfish to be inadvertently introduced as a contaminant when other biota are traded or moved for aquarial or ornamental purposes.
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 environment to keep them alive, survival is highly likely.
1.07	How likely is the organism to arrive during the months of the year appropriate for establishment?	VERY LIKELY	VERY HIGH	The Marbled Crayfish may be imported at any time of the year but it is more likely to become established in the warmer summer months as it grows better at temperatures over 20°C (Holdich 2011).
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. Alternatively, escape may be dependent on how securely live crayfish are stored and their proximity to a suitable water for survival. The species can climb vertical glass walls (Vogt 2008 as cited in Holdich 2011). The species is also tolerant of drying and has been reported to survive without water for up to three days. (Jones <i>et al.</i> 2008).
1.09	Estimate the overall likelihood of entry into Ireland based on this pathway?	HIGHLY LIKELY	VERY HIGH	There is no specific information available to assess the level of entry of this crayfish species to Ireland <i>via</i> this pathway. However, Marbled Crayfish are for sale in Ireland.
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). A variety of 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). It is considered very unlikely that live Marbled Crayfish is imported for use as food for humans or fish as the principal pathway for this species to enter Ireland is <i>via</i> the aquarium trade.
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?	VERY UNLIKELY	HIGH	It is very unlikely that Marbled Crayfish are imported to Ireland for use as food for humans. There are no known instances of non-native crayfish being stocked in Irish waters to provide a food source for fish. It may be appealing to some anglers to transfer this species to the wild to provide a supplemental food source for fish (Holdich 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 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 kept alive when moved <i>via</i> these pathways, making their survival very likely.
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?	UNLIKELY	HIGH	This is considered unlikely when live specimens are imported or traded for human consumption as it would necessitate escape to a suitable habitat or a deliberate act of introduction. However, direct transfer is virtually assured if stocked as a fish food source.
1.09	Estimate the overall likelihood of entry into Ireland based on this pathway?	VERY UNLIKELY	MEDIUM	As previously stated, it is very unlikely that Marbled Crayfish are imported for use as food for humans or fish as no such information was found.
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 that support populations of Marbled Crayfish has the potential to inadvertently transfer this 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?	VERY LIKELY	VERY HIGH	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	This is considered unlikely due to the low frequency of fish stocking undertaken from abroad. However, there remains some potential for introduction <i>via</i> this pathway, if the fish are sourced from a location where crayfish are present. It is likely that any such introduction would be associated with illegal stocking practices.
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 that supports populations of 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. The use of Marbled Crayfish as live bait for angling has been suggested as a potential mechanism responsible for the spread of this species (Holdich 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	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 in association with angling gear (e.g. keep nets) which are redeployed into a receiving water. This is also the case for live bait which could be dumped after a fishing excursion.
1.09	Estimate the overall likelihood of entry into Ireland based on this pathway?	UNLIKELY	MEDIUM	Although unlikely, there is some potential for entry <i>via</i> 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).		HIGH	The most likely pathway for Marbled Crayfish to gain entry to suitable waters in Ireland are considered to be through deliberate introduction from an aquarium dump.

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.
2.02	How likely is it that the organism will be able to establish in Ireland based on the similarity between local <u>climatic conditions</u> and the organism's current global distribution?	VERY LIKELY	VERY HIGH	<p>Climatic model analysis by Gallardo and Aldridge (2013) and Fera and Faulkes (2011) indicates that Marbled Crayfish are highly likely to establish in the majority of watercourses in Ireland. The wide range of climatic conditions tolerated by Marbled Crayfish in its introduced European range (refer to response to Question 8) indicate that this organism would be able to survive and establish in Ireland. Although, as continental European populations experience warmer summers than in Ireland, it is uncertain how vigorous any population establishment would be as spawning potential here could be limited (Souty-Grosset <i>et al.</i> 2006). The species can tolerate temperatures of < 8°C and > 30 °C for many weeks but mortality increases and reproduction is suspended under these conditions (Souty-Grosset <i>et al.</i> 2006). In addition, for successful reproduction, water temperatures of at least 20°C may be required (Souty-Grosset <i>et al.</i> 2006).</p> <p>According to Holdich (2011) "It may be that <i>Procambarus</i> sp. is a sub-tropical species and that it will not fare as well in temperate conditions –. If marmorkrebs is the slough crayfish, <i>Procambarus fallax</i> (Martin <i>et al.</i> 2010), then this species inhabits wetlands of peninsular Florida and southern Georgia in the USA, where the minimum winter temperature falls to 6°C in the north of its range. Similar climatic conditions apparently occur in Madagascar. Martin <i>et al.</i> (2010) wonder whether marmorkrebs could persist in northern and central European lakes or streams where temperatures drop to 4°C under ice for months. They mention that there is a record of an individual surviving under ice cover (Pfeiffer 2005) and the results of Seitz <i>et al.</i> (2005) show that it has substantial cold tolerance, although its temperature optimum is high at 18-25°C. The recent finding of a well-developed population in a lake in the region of the upper Rhine would seem to indicate that it can survive central European winter conditions (Chucholl, C. pers. comm. 2010)." Indeed, Chucholl <i>et al.</i> (2012) list populations in a number of ponds and lakes in Germany, near Frieberg, Tubiogen, Halle etc., and in Slovakia; most if not all of which would be ice-covered in winter (J. Reynolds pers. comm.).</p>

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
2.03	How likely is it that the organism will be able to establish in Ireland based on the similarity between other local <u>abiotic conditions</u> and the organism's current global distribution?	VERY LIKELY	VERY HIGH	Overall, abiotic conditions are not likely to prevent the establishment of Marbled Crayfish in Ireland (see response to Question 2.02 above and 2.04 below).
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 Europe, the Marbled Crayfish are found in both lotic and lentic freshwater habitats, including brooks, rivers, canals, natural and artificial lakes, and ponds. However, established populations have only been found in lentic habitats (Chucholl <i>et al.</i> 2012). There is an abundance of such habitats available for colonisation by Marbled Crayfish in Ireland.
2.05	How likely is it that establishment will occur despite competition from existing species in Ireland?	VERY LIKELY	HIGH	<p>Competition will occur from existing species but this is highly unlikely to prevent establishment. Fish may also provide competition for food resources, such as macroinvertebrates. It is highly likely that the native[†] White-clawed Crayfish would provide some direct competition for resources where both occur. However, Marbled Crayfish are very likely to out-compete the native crayfish species where both occur, even if they were not carrying the crayfish plague <i>Aphanomyces astaci</i> (Schikora). (Souty-Grosset <i>et al.</i> 2006; Martin <i>et al.</i> 2010).</p> <p>([†] 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 because of this, it is referred to as a native species in this risk assessment.</p>
2.06	How likely is it that establishment will occur despite predators, parasites or pathogens already present in Ireland?	VERY LIKELY	VERY HIGH	Predation is likely to occur from existing species such as perch, pike, heron, otter, mink and eels. Marbled Crayfish may act as a vector for the crayfish plague <i>Aphanomyces astaci</i> (Martin <i>et al.</i> 2010; Chucholl <i>et al.</i> 2012). Neither are likely to prevent establishment (Holdich 2011). 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.

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
2.07	How likely is it that establishment will occur despite existing management practices?	LIKELY	HIGH	In general, the state public management of waterways is undertaken to ensure that 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. Nevertheless, it is considered likely that this species can establish despite existing management practices, which can only mitigate for aspects of the establishment 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 establishment of non-native crayfishes in the wild in 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?	VERY LIKELY	HIGH	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 ineffective eradication method due to habitat complexity (Cosgrove <i>et al.</i> 2008).
2.10	How likely is it that the biological characteristics of the organism will facilitate its establishment?	VERY LIKELY	VERY HIGH	Marbled Crayfish reproduce by parthenogenesis, are capable of breeding a number of times each year, are more fecund than our native crayfish and have a rapid growth rate (Souty-Grosset <i>et al.</i> 2006; reviewed in Holdich 2011). As a result, they can rapidly establish high densities in suitable habitats (Jones <i>et al.</i> 2008; Chucholl <i>et al.</i> 2012). The species is able to survive periods out of water (Jones <i>et al.</i> 2008) and traverse land, which can aid its spread from confined locations.
2.11	How likely is it that the organism's capacity to spread will facilitate its establishment?	LIKELY	HIGH	The primary mode of spread in the wild is human-mediated (Jones <i>et al.</i> 2008; Chucholl <i>et al.</i> 2012). The species is able to survive periods out of water (Jones <i>et al.</i> 2008) and traverse land, which can aid its spread from confined locations. The potential high fecundity of the species is likely to facilitate spread within catchments.

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	HIGH	In general, crayfish are omnivorous, having the ability to act as herbivores, detritivores and predators. This non-specific, polytrophic character provides adaptability which will facilitate establishment in suitable habitats with varying food resources (reviewed in Souty-Grosset <i>et al.</i> 2006). Marbled Crayfish should be tolerant of Irish water temperatures. However, their reproductive capacity may be constrained in cool summers (refer to response to Question 2.02). They can occupy a variety of habitats that are abundant in Ireland (refer to response to Question 2.04). There is a paucity of further information to assess this in more detail.
2.13	How likely is it that the organism could establish despite low genetic diversity in the founder population?	VERY LIKELY	VERY HIGH	Despite the fact that Marbled Crayfish reproduce solely by parthenogenesis (Martin <i>et al.</i> 2010) and, therefore, likely have very low genetic variation, this appears not to have inhibited population establishment in European or Madagascarian populations (Jones <i>et al.</i> 2008; Chucholl <i>et al.</i> 2012).
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	HIGH	Based on the limited information available on the biological character and habitat preferences of Marbled Crayfish (Souty-Grosset <i>et al.</i> 2006; Chucholl <i>et al.</i> 2012), the species is very likely to establish in Ireland as climatic and abiotic conditions are considered suitable and there are a wide range of habitats available for colonisation. However, reproduction may be constrained in cool summers where water temperatures do not reach or exceed 20°C.
2.15	If the organism does not establish, then how likely is it that transient populations will continue to occur?	MODERATELY LIKELY	MEDIUM	Transient populations may occur as the temperature tolerance of the species should at least allow it to survive, but it may not successfully reproduce (refer to response to Question 2.04 for species temperature data). The lifespan of the species is uncertain (Souty-Grosset <i>et al.</i> 2006).
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 Marbled Crayfish can establish in the wild 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
3.01	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	Marbled crayfish could colonise a range of habitat types that are abundant in Ireland (refer to response to Question 2.04).
3.02	How important is the expected spread of this organism in Ireland by <u>natural</u> means (minimal, minor, moderate, major or massive)?	UNKNOWN	LOW	An assessment of the natural capacity of Marbled Crayfish to spread is, as yet, unavailable as European populations are only recently established (Holdich 2011). The species does have the documented ability to traverse over-land (Chucholl <i>et al.</i> 2012), giving it some capacity to spread from isolated waters.
3.03	How important is the expected spread of this organism in Ireland by <u>human assistance</u> (minimal, minor, moderate, major or massive)?	MAJOR	HIGH	Human-mediated introductions from aquarium dumps or transfers are more likely to be responsible for any inter-catchment spread (Holdich 2011) and these are considered the principal mechanism responsible for spread in Europe (Chucholl <i>et al.</i> 2012) and Madagascar (Jones <i>et al.</i> 2008) to date.
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, and the nature of the water colonised. Containment might be feasible in a closed system such as a pond, particularly if geographical isolated from other waters. It would be very difficult in an open water system (e.g. river catchment or lake) or semi-open system such as a canal because of its high ability to disperse by natural means. In general, the containment of other introduced invertebrates has been unsuccessful in Ireland.
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 the wild 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 the wild 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 the wild 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.	-		In Europe, the Marbled Crayfish are found in both lotic and lentic freshwater habitats, including brooks, rivers, canals, natural and artificial lakes, and ponds. However, established populations have only been found in lentic habitats (Chucholl <i>et al.</i> 2012). There is an abundance of such habitats available for colonisation by Marbled Crayfish in Ireland.
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 .			This primarily depends on the number of introductions that occur. An assessment of the natural capacity of Marbled Crayfish to spread is, as yet, unavailable as European populations are only recently established. Human-mediated introductions from aquarium dumps or transfers are more likely to be responsible for any inter-catchment spread (Holdich 2011).

Stage 2 - Detailed assessment: Section D - Impact				
<i>This section evaluates the probability of impact of an organism within Ireland.</i>				
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?	MINIMAL	MEDIUM	The only region that Marbled Crayfish are prevalent in is Madagascar. There are concerns there that it might impact on the rice crop but there is no evidence that this is happening yet (Jones <i>et al.</i> 2009; Holdich 2011).
4.02	How great has the economic cost of the organism been in Ireland from the <u>time of introduction to the present</u> ? Exclude any costs associated with managing the organism from your answer.	N/A		This species has not been recorded in the wild in Ireland to date.
4.03	How great is the economic cost of the organism likely to be in the <u>future</u> in Ireland? Exclude any costs associated with managing the organism from your answer.	MODERATE	MEDIUM	The establishment of dense populations of Marbled Crayfish may negatively affect the socio-economic value of recreational fisheries, as has occurred in Britain as a result of the establishment of abundant Signal Crayfish populations (Holdich 2011).
4.04	How great have the economic costs of managing this organism been in Ireland from the <u>time of introduction to the present</u> ?	N/A		This species has not been recorded in the wild in Ireland to date.
4.05	How great is the economic cost of managing this organism likely to be in the <u>future</u> in Ireland?	MODERATE	MEDIUM	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 this species. 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?	UNKNOWN	LOW	According to Holdich 2011, "None have been reported from mainland Europe. Studies are in progress in Madagascar to ascertain whether it is damaging the rice crop". Little is known about the trophic position and ecological impact of Marbled Crayfish as it has only recently established in the wild. Given the major impacts of the related species such as <i>Procambarus clarkii</i> on recipient ecosystems (Souty-Grosset <i>et al.</i> 2006, and citations therein), Marbled Crayfish may have a profound impact on the species richness, functioning and integrity of ecosystems (Chucholl <i>et al.</i> 2012).

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	N/A		This species has not been recorded in the wild in Ireland to date.
4.08	How important is the impact of the organism on biodiversity likely to be in the <u>future</u> in Ireland?	MAJOR	HIGH	The establishment of Marbled Crayfish 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 Habitat's Directive protected Annex 2 listed species and classified as vulnerable and rare in the IUCN Red List of threatened animals. It is also recognised to be of national importance with legislation enacted to protect under the Wildlife Act 1976 in Ireland. It is likely that both crayfish species would occupy similar ecological niches and habitats and it is considered that Marbled Crayfish would displace the native crayfish due to their faster growing nature and enhanced reproduction capability (reviewed in Holdich 2011 and Chucholl <i>et al.</i> 2012). It may also carry and transmit crayfish plague.
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 the wild in Ireland to date.
4.10	How important is alteration of ecosystem function caused by the organism likely to be in Ireland in the <u>future</u> ?	MAJOR	HIGH	As 'ecosystem engineers', crayfish in general have the ability to alter ecosystem function through food-web or habitat modification (Jones <i>et al.</i> 1997). The degree of change would likely depend on the extent of colonisation. The high population densities that can be attained by Marbled Crayfish in invaded ecosystems (Jones <i>et al.</i> 2008; Chucholl pers. comm. as cited in Holdich 2011) may increase the potential for ecosystem function to be altered.
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 the wild 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 <u>future</u> in Ireland?	MAJOR	HIGH	The establishment of Marbled crayfish may have detrimental impacts to 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 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	MEDIUM	According to Holdich (2011), " <i>Procambarus</i> sp. only occurs in any numbers in Germany, the Netherlands and Madagascar, where it has been introduced in all cases. Only in Madagascar is it likely to cause social harm by destroying crops, such as rice. However, in Madagascar it has been beneficial socially as it is on sale in many fish markets and is proving an additional source of food and revenue (Jones <i>et al.</i> 2009)".
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 the wild 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	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)?			This species can act as a vector of the crayfish plague (reviewed in Holdich 2011) and could spread it to the native White-clawed Crayfish.
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?	MAJOR	HIGH	Natural control by other organisms is unlikely to affect expected impacts (i.e. displacement of the native White-clawed Crayfish) (Holdich 2011).

Stage 2 - Detailed assessment: Section D - Impact				
<i>This section evaluates the probability of impact of an organism within Ireland.</i>				
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.	-		Potential environmental and social impacts are possible wherever Marbled Crayfish could establish. There is an abundance of such waters in Ireland. The conservation status of waters which hold native White-clawed crayfish stock would be directly threatened.
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 Marbled Crayfish in Ireland is the threat it poses to the native White-clawed Crayfish. In addition, native biodiversity and ecosystem function are also likely to be threatened if abundant populations establish in the wild in Ireland. Furthermore, this non-native crayfish species could interfere with recreational fisheries.

Stage 2 - Detailed assessment: Section E - Conclusion				
<i>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.</i>				
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 conservation status of native White-clawed Crayfish populations in Ireland. In addition, native biodiversity and ecosystem function are also likely to be threatened if abundant populations establish in the wild in Ireland. Furthermore, this non-native crayfish species could interfere with recreational fisheries.

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	<p>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 <i>et al.</i> 2008). An increase in water temperatures is likely to enhance the fecundity and growth of Marbled Crayfish (refer to response to Question 2.04 for temperature tolerances and optimal temperatures for growth and reproduction). If water temperatures of at least 20°C are required for reproduction (Souty-Grosset <i>et al.</i> 2006), an increase in water temperature as a result of climate change should facilitate reproduction and enhance capacity for establishment and spread in Ireland.</p> <p>The species tolerance to drought is likely to increase its ability to withstand any prolonged periods of drought that may occur in Ireland (Jones <i>et al.</i> 2008).</p>
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		HIGH	The establishment and invasive potential of Marbled crayfish is likely to increase in Ireland, as outlined in response to Question 6.01.
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	HIGH	Specific information on the extent of import and sale of Marbled Crayfish in Ireland through the aquarium trade would strengthen the risk assessment. In addition, it is likely that more comprehensive information on the ecology and impacts of this species will be ascertained as it further establishes populations in Europe and elsewhere which can then be used to strengthen this risk assessment.

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