Risk Assessment of *Procambarus clarkii*

Name of Organism:	*Procambarus clarkii* (Girard 1852) – Red Swamp 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.

DOCUMENT CONTROL SHEET

Name of Document:	Risk Assessment of *Procambarus clarkii*				
Author (s):	Dr Michael Millane and Dr Joe Caffrey				
Authorised Officer:	Dr Joe Caffrey				
Description of Content:	Non-native species risk assessment				
Approved by:	Dr Cathal Gallagher				
Date of Approval:	15/09/2014				
Assigned review period:	n/a				
Date of next review:	n/a				
Document Code	n/a				
This documents comprises	TOC	Text	List of tables	List of Figures	No. Appendices
	n/a	YES	n/a	n/a	0

Version Control Table

Version No.	Status	Authors(s)	Reviewed by	Approved by	Date of issue
Draft 1	Complete	Dr Michael Millane	Dr Joe Caffrey		03/03/2014
Expert review	Complete	Dr Michael Millane	Dr Julian Reynolds	Dr Joe Caffrey	14/03/2014
Public Consultation 1	Complete	Dr Michael Millane	Dr Joe Caffrey		09/05/2014
Public Consultation 2	Complete	Dr Michael Millane	Dr Joe Caffrey		14/08/2014
Final	Complete	Dr Michael Millane	Dr Joe Caffrey	Dr Cathal Gallagher	15/09/2014

Stage 1 - Organism Information *The aim of this section is to gather basic information about the organism.*			
N	**QUESTION**	**RESPONSE**	**COMMENT**
1	What is the reason for performing the risk assessment?		A risk assessment is required as this species is listed as a "Non-native species subject to restrictions under Regulations 49 and 50" in the Third Schedule of the European Communities (Birds and Natural Habitats) Regulations 2011, SI 477/2011.
2	Identify the organism. Is it clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?	YES	*Procambarus clarkii* (Girard 1852) or (Hobbs1942), *Cambarus clarkii* Girard 1852 *Cambarus clarkii* Faxon 1898; Red Swamp Crayfish; Louisiana Crayfish / Crawfish (Souty-Grosset *et al*. 2006).
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.	-	*Procambarus clarkii* is characterised by red, sinuous claws which are covered dorsally in tubercles and spines. The body colour is dark red, orange or reddish-brown but brown to olive-green when young (Holdich and Sibley 2009). More diverse colour patterns may be evident in ornamental stock bred for the aquarium trade (Declan MacGabhann pers. comm.). Total length is ≤ 15 cm, but more typically 10 cm (Souty-Grosset *et al.* 2006). A more detailed identification is provided in FAO (2014).
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 *Procambarus clarkii* 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?		Southern USA (Florida, and north to southern Illinois and Ohio) and Northern Mexico (FAO 2014).
8	What is the current global distribution of the organism (excluding Ireland)?		According to FAO (2014) *Procambarus clarkii* is "widely introduced in the United States (Arizona, California, Georgia, Hawaii, Idaho, Indiana, Maryland, Nevada, New Mexico, North Carolina, Ohio, Oregon, South Carolina, Utah, Oklahoma), south and central America (Belize, Brazil, Costa Rica, Dominican Republic)… and other more dispersed areas (Japan, Kenya, China, Taiwan, and Uganda)". It is also recorded in13 European countries including Austria, England, France, Germany, Italy, Portugal, Spain, Switzerland and The Netherlands and on some European islands (Azores, Canary Islands, Cyprus, Sardinia and Sicily) (Souty-Grosset *et al*. 2006).

Stage 1 - Organism Information *The aim of this section is to gather basic information about the organism.*			
N	**QUESTION**	**RESPONSE**	**COMMENT**
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?		According to GB Non-Native Species Secretariat (2011), *Procambarus clarkii* "is expanding its range within the EU and trans-nationally (e.g. spread into Portugal from legal introduction for aquaculture in Spain, with severe impact on indigenous populations of White-clawed Crayfish). Economic and other environmental damage is recorded in California, Hawaii, Japan, Kenya, Spain, Portugal (Holdich 1999; Huner 2000) also in Garonne wetlands in France. It is a banned species in parts of the USA (Virginia as bait, Missouri, New Hampshire, Florida ban on import, sale, possession or transport, Maryland ban on transport; Fishforum website, Taylor *et al*. 2007)."

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	A variety of potentially invasive, non-native crayfish, including *Procambarus clarkii,* are periodically for sale in Irish aquarium shops and can be purchased on the internet (Reynolds and O'Keeffe 2009). It is also bred and traded among some aquarium hobbyists. 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?	LIKELY	MEDIUM TO HIGH	Web searches carried out by the authors indicate that *Procambarus clarkii* is currently one of the most popular non-native crayfish species used in aquaria in Ireland (e.g. it is advertised for private sale on Donedeal.ie in Cork, listed for purchase by aquarium retailers, discussed in aquarium fora and videos of specimens in aquaria are posted on YouTube). However, comprehensive data is not available to assess the extent of trade. Therefore, it is rated as likely but with medium to high confidence.
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.

Pathway 1 – Aquarium trade				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
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.
1.07	How likely is the organism to arrive during the months of the year appropriate for establishment?	VERY LIKELY	VERY HIGH	In the UK it is considered that *Procambarus clarkii* can survive an introduction at any time of year (GB Non-Native Species Secretariat 2011). This is likely the case for Ireland. 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) 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?	MODEASTELY 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. They do have some ability to walk over-land to access watercourses (Holdich *et al*. 2002). The breeding of *Procambarus clarkii* by aquarium hobbyists heightens the risk of such introductions.
1.09	Estimate the overall likelihood of entry into Ireland based on this pathway?	VERY LIKELY	VERY HIGH	Although, there is no specific information available to assess the level of entry of this crayfish species to Ireland *via* this pathway, it is known that *Procambarus clarkii* are imported and are for sale in the country, and further distributed and bred by aquarium hobbyists.
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). Live *Procambarus clarkii* are regularly imported into Ireland *via* the food trade for human consumption (Declan MacGabhann pers. comm.).
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 LIKELY	HIGH	Live *Procambarus clarkii* for human consumption are principally imported to Ireland from Billingsgate Market in London, England and from France (Declan MacGabhann pers. comm.). Although no specific information on the frequency of such imports is available, they do occur on a regular basis (Declan MacGabhann pers. comm.). However, the frequency of such imports has declined since the end of the 'Celtic Tiger' period when consumer demand dropped (Declan MacGabhann pers. comm.). Therefore, it is considered very likely that large numbers of live *Procambarus clarkii* will travel by this pathway into the country. Deliberate dumping of surplus or undersized crayfish could occur. There are no known instances of non-native crayfish being stocked (or recorded) in Irish waters to provide a food source for fish.
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 *via* these pathways to ensure their survival. They are imported in wooden crates in a damp environment and are sometimes placed in cold storage after import (Declan MacGabhann pers. comm.).
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. Direct transfer is virtually assured if stocked as a fish-food source. Imported living crayfish are unlikely to be imported and stocked as fish food but more likely to be discarded live as surplus from the food trade.

Pathway 2 – Food trade for humans or fish				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
1.09	Estimate the overall likelihood of entry into Ireland based on this pathway?	VERY LIKELY (for human consumption)	VERY HIGH (for human consumption)	As previously stated, live *Procambarus clarkii* are imported into Ireland *via* the food trade for human consumption (Declan MacGabhann pers. comm.). There are no known instances of non-native crayfish being stocked in Irish waters to provide a food source for fish (so in this case a rating is given as 'very unlikely' with 'high' confidence).
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 *Procambarus clarkii* 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 (unless legislation ensures that only cooked crayfish are traded).
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.

Pathway 3 – Fish stocking				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
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 *via* 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 these species to Ireland. In addition, if used as live bait for angling there is potential for escape.
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.

Pathway 4 – Angling				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
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 *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).	VERY 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 for human consumption.

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 climatic conditions and the organism's current global distribution?	VERY LIKELY	VERY HIGH	The wide range of climatic conditions experienced by *Procambarus clarkii* in its introduced range indicates that this organism would be able to survive and establish in Ireland. Climatic model analyses by Gallardo and Aldridge (2013) and Liu *et al*. 2011 suggest that *Procambarus clarkii* is highly suited to and could readily establish in the vast majority of watercourses in Ireland. A review in the Global Invasive Species Database (2011) states that *Procambarus clarkii* " thrives in warm, shallow wetland ecosystems of natural and agricultural lands as in the case of south and central Europe where it has established (Henttonen and Huner, 1999). In the cooler regions of Europe, it prefers small, permanent ponds because it is unable to survive predation by fishes in large water bodies (Troschel and Dehus 1993; Roqueplo *et al* 1995; Delmastro and Laurent 1997, Huner pers. obs., in Henttonen and Huner 1999)." Optimal water temperatures for growth are 21-27°C and growth inhibition occurs at temperatures below 12°C (Ackefors 1999). It should be noted that an attempt to introduce *Procambarus clarkii* into southern Sweden was unsuccessful and this was attributed to the species being adapted to survive in warmer waters (Blindow *et al*. 1984 as cited in Olsson 2005). *Procambarus clarkii* have been demonstrated to survive and reproduce in a private aquarium subject to ambient outdoor temperatures in Ireland over a three year period. This period included the exceptionally cold winter of 2009/10 (Declan MacGabhann pers. comm.) where temperatures reached as low as minus 10^{o} C.
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 sufficiently limiting in Ireland to prevent the establishment of *Procambarus clarkii*. The species is tolerant and adaptable to a wide range of aquatic conditions including moderate salinity, fluctuations in acidity, low oxygen levels, extreme temperatures and pollution (reviewed in Global Invasive Species Database 2011).Water temperatures should be high enough to facilitate breeding (see response to Question 2.02 above).

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
2.04	How likely is the organism to encounter habitats necessary for the survival, development and multiplication of the organism in Ireland?	VERY LIKELY	VERY HIGH	*Procambarus clarkii* can inhabit a wide variety of freshwater habitats including rivers, lakes, canals, ponds, streams and seasonally flooded marshes and swamps. The species also frequently inhabits disturbed environments such as irrigation channels and reservoirs (reviewed in Global Invasive Species Database 2011). 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 with resident species but this is not likely 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, *Procambarus clarkii* is very likely to out-compete the native crayfish species in most or all habitats, even if *Procambarus clarkii* were not carrying the crayfish plague *Aphanomyces astaci* (Schikora) (GB Non-Native Species Secretariat 2011). *Procambarus clarkii* was found to be dominant in antagonistic interactions with similar-sized White-clawed Crayfish (Gherardi *et al*. 1999 as cited in Gherardi *et al*. 1999). It has also severely reduced the range of the White-clawed Crayfish in both Spain and Portugal (Holdich 1999 as cited in Global Invasive Species Database 2011). († 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.
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, but is highly unlikely to prevent establishment. *Procambarus clarkii* is a chronic carrier of the crayfish plague *Aphanomyces astaci* but is itself highly resistant to it, except under stressful conditions or when it is exposed to high spore content (Souty-Grosset *et al*. 2006). 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	According to Gherardi (2006), "Unfortunately, several attempts to date to reduce the impact of *Procambarus clarkii* …in Europe …have failed, suggesting that, once this species is established, eradication may be impossible". 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 *et al*. 2008) and the burrowing nature of this crayfish species (Barbaresi and Gherardi 2000).
2.10	How likely is it that the biological characteristics of the organism will facilitate its establishment?	VERY LIKELY	VERY HIGH	According to Gherardi (2006), "*Procambarus clarkii* shows that several life history traits (early maturity, rapid growth, large number of offspring, and plastic life cycle) and biological features (tolerance to extreme environments, dispersal, polyphagy, predatory and competitive ability, and behavioural flexibility) predispose this species to spread and to become invasive." It exhibits characteristics of an r-selected species. This includes early maturity at small body size (10 g), rapid growth rates (50 g in 3–5 months) and the production of large numbers of offspring. An average sized female can produce 400 pleopodal eggs, which is about four times that produced by a similarly sized native White-clawed crayfish (reviewed in Gherardi 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
2.11	How likely is it that the organism's capacity to spread will facilitate its establishment?	VERY LIKELY	HIGH	This would depend on the extent of initial introduction(s). The literature indicates that *Procambarus clarkii* has a high capacity for spread once it is introduced to the wild. As a result of natural expansion since its arrival in Spain in the mid- to late 1970s, *Procambarus clarkii* has since spread to most inland waters (Holdich *et al*. 2002). It was introduced to western France in 1974 and by 1990 had spread to 14 Departments (i.e. administrative regions) and by 1995 to 36 Departments (Holdich *et al*. 2002). Since its introduction to Italy in 1983, it has become well established in northern and central parts of the country (Holdich *et al*. 2002). *Procambarus clarkii* has been known to move over 3 km per day and breeding males have been documented to move up to 17 km in four days (reviewed in Barbaresi and Gherardi 2000). Individuals are able to traverse land and are thus not solely restricted to the aquatic environment to colonise new waters (Souty-Grosset *et al*. 2006).
2.12	How likely is it that the organism's adaptability will facilitate its establishment?	VERY LIKELY	VERY 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 (reviewed in Souty-Grosset *et al*. 2006). It is also tolerant of a range of environmental conditions (refer to response to Question 2.03) and can occupy a variety of habitats (refer to response to Question 2.054)
2.13	How likely is it that the organism could establish despite low genetic diversity in the founder population?	LIKELY	LOW	There is no information available to comment on this. However, low genetic variation in Irish populations of *A. pallipes* has not hindered their spread (Gouin *et al*. 2003).

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
2.14	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 a review of its biological character and ecological requirements in its native and introduced range, *Procambarus clarkii* 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. This is supported by its documented survival and ability to reproduce in a private aquarium subject to ambient outdoor temperatures in Ireland over a three year period despite being subjected to an exceptionally cold winter (Declan MacGabhann pers. comm.). Its fast rate of spread after introduction to a number of European countries (refer to response to Question 2.11) further supports this.
2.15	If the organism does not establish, then how likely is it that transient populations will continue to occur?	UNLIKELY	VERY HIGH	Transient populations are unlikely to occur as it is considered very likely from the information reviewed 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 *Procambarus clarkii* can establish in the wild in Ireland. This is further supported by its documented survival and ability to reproduce in a private pond in Ireland as mentioned above.

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)	VERY HIGH	*Procambarus clarkii* could colonise a range of habitat types which 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 natural means (minimal, minor, moderate, major or massive)?	MAJOR	VERY HIGH	The rate of natural spread of *Procambarus clarkii* after introduction to a number of European countries has been rapid (refer to response to Question 2.11) and this is likely to be the case if the species is introduced to the wild in Ireland. The ability of *Procambarus clarkii* to traverse overland to colonise other waters (Souty-Grosset *et al.* 2006) and its potential for moving up to 3 km per day within a catchment (reviewed in Barbaresi and Gherardi 2000) enhances the capability for natural spread.
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 to increase the rate of dispersal of the species in Ireland, especially between catchments. Such inter-catchment transfers may occur to provide local food sources for humans or fish, or the species may be transferred by anglers for use as live fish bait. In addition, aquarium dumps also have a high potential to spread *Procambarus clarkii*.
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 would be feasible in a closed system such as a pond, particularly if geographical isolated from other waters. Containment 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 capacity 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.	-		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 .			If introduced, the potential for subsequent spread is very high. This primarily depends on the number of introductions and the suitability of the waters they are introduced into.

Stage 2 - Detailed assessment: Section D - Impact

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

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
4.01	How great is the economic loss caused by the organism within its global distribution (excluding Ireland), including the cost of any current management?	MAJOR	MEDIUM	According to GB Non-Native Species Secretariat (2011) there is "major economic impact in rice-growing areas, due to grazing (e.g. Anastacio and Marques 1996) and damage of drainage/irrigation systems. Commercial European production of Red Swamp Crayfish in southern Europe is relatively low, estimated at around 3000-5000t/yr (Souty-Grosset *et al*. 2006) and a small number of producers enjoy economic benefits, but the economic impact of damage amounts to £100s millions/year (D. M. Holdich, F. Gherardi, pers. comm.). There is some uncertainty of the economic cost within Europe." The burrowing activity of *Procambarus clarkii* has been known to undermine riverbanks, levees and dikes, increasing erosion (reviewed in Correia and Ferreira 1995 and Global Invasive Species Database 2011). Commercial fisheries have been negatively impacted by the species damaging nets, preying on fish eggs and through habitat alteration, principally by removing macrophytes. This results in undesirable turbid aquatic conditions (reviewed in Global Invasive Species Database 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 the wild 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	MEDIUM	The burrowing activity of *Procambarus clarkii* has the potential to cause bankside erosion and collapse, and to block irrigation or drainage channels as a result (refer tor response to Question 4.01). Commercial fisheries may be negatively impacted by the species damaging nets, preying on fish eggs, competing with fish for food resources or altering food-webs, which may affect fish stocks (reviewed in Global Invasive Species Database 2011). Some of these may also negatively affect recreational fisheries.

Stage 2 - Detailed assessment: Section D - Impact *This section evaluates the probability of impact of an organism within Ireland.*				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
4.04	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 the wild 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	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 *Procambarus clarkii.* 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?	MAJOR	VERY HIGH	*Procambarus clarkii* introductions can cause dramatic changes in native plant and animal communities, severely impact native crayfish through competition and transition of the crayfish plague, reduce macrophyte assemblages and diversity, alter water quality and sediment characteristics, accumulate heavy metals, interact with additional invasive species and reduce populations of invertebrates, molluscs and amphibians through predation and competition (reviewed in Global Invasive Species Database 2011). Further to this, *Procambarus clarkii* "is known to compete with, prey on, and reduce populations of a wide variety of aquatic species including amphibians, molluscs, macroinvertebrates, and fish" (Global Invasive Species Database 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 the wild 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	HIGH	The establishment of *Procambarus clarkii* 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

Stage 2 - Detailed assessment: Section D - Impact *This section evaluates the probability of impact of an organism within Ireland.*				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
				that *Procambarus clarkii* would displace the native crayfish due to its relatively large size, faster growing nature and enhanced reproduction capability (Reynolds 1998; reviewed in Gherardi 2006). The reviewed literature also indicates that *Procambarus clarkii* could "reduce populations of a wide variety of aquatic species including amphibians, molluscs, macroinvertebrates and fish" (Global Invasive Species Database 2011). Other species likely to be impacted by *Procambarus clarkii* in Irish wetlands include the common frog and common newt protected by the Wildlife Acts, Opposite-leaved Pondweed (ditches around Lower Shannon) and perhaps Triangular Club-rush protected under the Flora Protection Orders.
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 future?	MAJOR	HIGH	As 'ecosystem engineers', crayfish in general have the ability to alter ecosystem function through food-web or habitat modification (Jones *et al*. 1997). The high population densities that can be attained by *Procambarus clarkii* in invaded ecosystems may increase the potential for ecosystem function to be altered (Gherardi 2006). The species would likely become a novel food resource for a variety of waterfowl and fish species in Ireland (notably pike, perch and eels) and it would prey on the eggs of a number of fish species and fish (reviewed in Reynolds 2011). It may reduce the stability of aquatic systems by causing a shift from macrophyte-dominated state to a phytoplankton-dominated turbid condition (Matsuzaki *et al*. 2009). Such macrophyte removal can reducing spawning substrate and cover for fish species like Perch, Pike and some coarse fish species (reviewed in Reynolds 2011). The degradation of swamps to muddy devegetated pool areas in the Camargue (Rhone Delta) and in Lake Naivasha (Africa) (Foster and Harper 2007) is indicative of possible impacts. On the other hand, herons and bitterns have increased in the Camargue (J. Reynolds pers. comm.). All of this may ultimately affect ecosystem function (reviewed in Reynolds 2011) with the degree of change likely dependant on the extent of colonisation and population densities attained.

Stage 2 - Detailed assessment: Section D - Impact

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

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
4.11	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.
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 *Procambarus clarkii* may have detrimental impacts to native White-clawed Crayfish populations in Ireland (refer to response to Question 4.08) and to other protected species (refer to response to Question 4.09). 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	*Procambarus clarkii* is an intermediate host of trematodes of the genus *Paragonimus*, which are potential pathogens of humans if undercooked crayfish are consumed (Gherardi and Panov 2006).
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)?	MAJOR	HIGH	*Procambarus clarkii* is an internationally esteemed food organism. This species is a chronic carrier of the crayfish plague (Souty-Grosset *et al*. 2006) 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 (Reynolds and Souty-Grosset 2012) which is already established in the Irish wild.

Stage 2 - Detailed assessment: Section D - Impact *This section evaluates the probability of impact of an organism within Ireland.*				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
4.17	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). Laboratory experiments have demonstrated the wide behavioural flexibility of *Procambarus clarkii* to responds to new types of predators. This ability might contribute to its success in new environments that may contain novel predators (reviewed in Gherardi 2006). A literature review by Reynolds (2011) suggests that the stock stability of *Procambarus clarkii* is correlated with high productivity and fast biomass turnover in its populations. A pond population was found to remain stable over a three years study period despite the presence of numerous Pike and Perch predators, a high predation pressure and annual trapping (Neveu 2001 as cited in Reynolds 2011). However, in a small artificial impoundment in Switzerland, introduced European Eels substantially reduced an expanding *Procambarus clarkii* population to less than 10% within three years, whereas Pike, introduced at the same time had no obvious effect. From this it was concluded that the effect of predatory fish is highest if shelter is sparse (Frütiger and Müller 2002 as reported in Reynolds 2011). Laboratory and field experiments in Italy assessing the use of European Eel to control *Procambarus clarkii* found that eels ambushed small and soft-shell crayfish from behind, and the presence of eels indirectly reduced crayfish trophic activity (Aquiloni *et al.* 2010 as reported in Reynolds 2011).
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 economic, environmental and social impacts are possible wherever *Procambarus clarkii* could establish. There is an abundance of such waters and wetlands in Ireland. In France, the species has spread through swampy areas (The Camargue, the Brenne Marshes) and comparable areas in Ireland, such as Callows, may be impacted (J.

Stage 2 - Detailed assessment: Section D - Impact *This section evaluates the probability of impact of an organism within Ireland.*				
N	**QUESTION**	**RESPONSE**	**CONFIDENCE**	**JUSTIFICATION**
				Reynolds pers. comm.). 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 *Procambarus clarkii* in Ireland is the threat it poses to the native White-clawed Crayfish. In addition, native biodiversity and ecosystem function are likely to be threatened if abundant populations establish in the wild in Ireland. Furthermore, this non-native crayfish species could interfere with bank stability, block drainage and irrigation channels and reduce the value of commercial and recreational fisheries.

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 conservation of the native White-clawed Crayfish populations and amphibians 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 bank stability, block drainage and irrigation channels and reduce the value of commercial and 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	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). An increase in water temperatures is likely to enhance the fecundity and growth of *Procambarus clarkii* (Ackefors 1999; Gherardi 2006). It is also drought tolerant, retreating to its burrows under dry conditions. This increases its ability to withstand any prolonged periods of drought that may occur (GB Non-Native Species Secretariat 2011). A global spatial

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
				analysis of two future climate change scenarios (50 years for now) suggests that the colonisation potential of *Procambarus clarkii* will increase in Ireland and that the current climate in Ireland is already suitable for the species (Liu *et al*. 2011). Further to this, laboratory experiments have shown that the *Procambarus clarkii* can survive and maintain high growth rates at temperatures higher than those tolerated by the native White-clawed Crayfish (reviewed in Gherardi and Holdich 1999). In addition, the presence of breeding populations in parts of central and northern Italy suggests that low temperatures are not, as reported elsewhere in the literature, a factor that limits their reproductive success and the distribution of the species (Gherardi and Holdich 1999).
6.02	What is the likely timeframe for such changes (5, 10, 15 , 20, 50 or 100 years)?	50	LOW	The response is based on the climate change model spatial analyses presented by Liu *et al*. (2011)
6.03	What aspects of the risk assessment are most likely to change as a result of climate change		HIGH	The colonisation potential of *Procambarus clarkii* 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 amount and frequency of *Procambarus clarkii* imports to Ireland for the food and ornamental trades would be useful to strengthen the pathways section of this risk assessment.

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